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IS 13408-1 (1992): Code of Practice for the Selection, Installation and Maintenance of Electrical Apparatus for Use in Potentially Explosive Atmospheres (Other Than Mining Applictions or Explosives Processing and Manufacture), Part 1: General Recommendations [ETD 22: Electrical Apparatus for Explosive Atmosphere]

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भाग 1 सामान्य अपेक्षाएं

Indian Standard

CODE OF PRACTICE FOR THE SELECTION, INSTALLATION AND MAINTENANCE OF ELECTRICAL APPARATUS FOR USE IN POTENTIALLY EXPLOSIVE ATMOSPHERES (OTHER THAN MINING APPLICATIONS OR EXPLOSIVES PROCESSING AND MANUFACTURE)

PART 1 GENERAL RECOMMENDATIONS

(First Reprint JANUARY 2004)

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BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

October 1992 **Price Group 12**

Electrical Apparatus for Explosive Atmospheres Sectional Committee, ET 22

CONTENTS

PAGE

Section 1 General

1. Scope ... 1
2. Reference Standards ... 1
3. Definitions and Explanation of Terms ... 1
4. Statutory Requirements ... 2
5. Classification of Hazardous Areas ... 2
6. Types of Protection ... 3
7. Light Metals as Constructional Materials ... 4

Section 2 Selection of Apparatus

8. Procedure for Selecting Electrical Apparatus ... 4
9. Interconnection of Apparatus ... 6

Section 3 General Installation Recommendations

10. General ... 6
11. Access for Inspection ... 6
12. Plans and Records ... 6
13. Electrical Ratings ... 6
14. Installation of Apparatus ... 6
15. Integrity of Insulation ... 7
16. Automatic Overcurrent Protection ... 7
17. Earthing and Earth Fault Protection ... 7
18. Isolation ... 7
19. Emergency Supplies ... 7
20. Wiring Systems ... 7
21. Portable and Transportable Apparatus and Its Connections ... 10

Section 4 Inspection, Maintenance and Testing

22. General ... 10
23. Personnel ... 10
24. Isolation of Apparatus ... 10
25. Precautions Concerning the Use of Igniting Agencies ... 10
26. Initial and Periodic Inspections ... 10
27. Initial and Periodic Testing ... 12
28. Maintenance Recommendations ... 12

Section 5 Properties of Flammable Liquids, Vapours and Gases

29. General ... 13
30. Melting Point and Boiling Point ... 13
31. Relative Vapour Density ... 13
32. Flash Point ... 13
33. Limits of Flammability ... 13
34. Flammability Range ... 13
35. Effect of Environments with Other Than Normal Atmospheric Conditions 14
36. Ignition Temperature ... 14
37. General Consideration ... 14

Section 6 Marking of Apparatus

38. General ... 15
39. Marking Requirements for Apparatus ... 15
40. Examples of Marking of Apparatus ... 16
41. General Notes on Marking ... 17

Annex A List of Referred Indian Standards ... 18
Annex B Relevant International, European and British Standards and Details of the National Certifying Authority and Its Certification Standards ... 19
Annex C Frictional Sparking Risks with Light Metals and Their Alloys 21
Annex D Data for Flammable Materials ... 22
Annex E Calculation of the Flammability Limits for a Mixture of Gases ... 35

(Continued on third cover)

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TO
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PART 1 GENERAL RECOMMENDATIONS

(*Page* 2, *clause* **4**) — Delete and renumber the subsequent clauses.

(*Page* 20, *clauses* **B-4**, **B-4.1**, **B-5** *and* **B-5.1**) — Delete and renumber the subsequent clauses.

(ET 22)

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Indian Standard

CODE OF PRACTICE FOR THE SELECTION, INSTALLATION AND MAINTENANCE OF ELECTRICAL APPARATUS FOR USE IN POTENTIALLY EXPLOSIVE ATMOSPHERES (OTHER THAN MINING APPLICATIONS OR EXPLOSIVES PROCESSING AND MANUFACTURE)

PART 1 GENERAL RECOMMENDATIONS

Section 1 General

1 SCOPE

1.1 This code gives recommendations for selection, installation and maintenance of electrical apparatus for use in areas where potentially explosive materials are generated, processed, handled, stored or otherwise encountered.

1.2 Flammable or potentially explosive materials in this standard include gases, vapours, mists and solids.

1.3 This standard applies to the following:

a) thermal effects where those give rise to danger in flammable or potentially explosive atmosphere;

b) protection against overcurrent where relevant to circuits in flammable or potentially explosive atmospheres;

c) methods for switching and isolation of electrical systems where relevant to circuits in flammable or potentially explosive atmospheres.

1.4 This code does not cover the following:

a) inherently explosive atmospheres, for example, explosives manufacturing and processing;

b) underground mining application;

c) dust atmospheres;

d) areas where abnormal atmospheric conditions occur;

e) the effects of static electricity and high frequency electromagnetic radiation.

NOTE — Detailed guidance on protection against risks due to static electricity may be found in IS 7689 : 1989.

1.5 This standard is applicable to all new permanent installations and, where resonably practicable, to existing installations. The recommendations for maintenance are applicable to all installations.

1.6 The recommendations of the standard are also applicable to those installations that are semi-permanent or temporary but alternative safety measures and procedures may need to be adopted to achieve the same level of safety as that recommended in this standard.

NOTES

1 This standard does not give guidance on methods of protection against electric shock, the effects of lightning (*see* IS 2809 : 1969), ignitions sources other than those associated with electrical apparatus or toxic risks. The toxic risks associated with flammable materials apply to concentrations that are usually very much less than the lower flammable limit.

2 Annex B contains, for information, a list of relevant international, European and British Standards, together with details of the national certifying authority and its certification standards.

2 REFERENCES

The list of Indian Standards given in Annex A is a necessary adjunct to this standard.

3 DEFINITIONS AND EXPLANATION OF TERMS

3.0 For the purpose of this part and of the other parts of the code generally, the following definitions shall apply.

NOTE — Further definitions that are particularly relevant to specific types of protection are included in the appropriate parts of this code of practice.

3.1 Explosive Atmospheres

A mixture of flammable gas or vapour with air under atmospheric conditions in which, after ignitions, combustion rapidly spreads throughout the unconsumed mixture.

3.2 Mist

A free suspension in air of droplets of a liquid whose vapour is flammable in free suspension in air.

3.3 Hazard

The presence, or the risk of the presence, of an explosive atmosphere.

3.4 Hazardous Area

An area in which explosive atmospheres are, or may be expected to be, present in quantities such as to require special precautions for the construction and use of electrical apparatus.

3.5 Non-Hazardous Area

An area in which explosive atmospheres are not expected to be present in such quantities that special precautions for the construction and use of electrical apparatus are necessary.

3.6 Flash Point

The lowest temperature at which sufficient vapour is given off from a flammable material to form an explosive atmosphere.

3.7 Ignition Temperature

The lowest temperature of a flammable gas or vapour at which ignition occurs when tested as described in IS 7820 : 1975.

NOTE — Ignition temperature was formally known as auto-ignition or spontaneous ignition temperature.

3.8 Accessible Surface

A surface to which an explosive atmosphere has access, and that is not explosion protected other than by temperature limitation.

3.9 Maximum Surface Temperature

The highest temperature attained under practical conditions of operation within the rating of the apparatus (and recognized overloads, and including defined fault conditions, if any, associated therewith) by an accessible surface the exposure of which to an explosive atmosphere may involve a risk.

3.10 Temperature Class (T Class)

One of six values of temperature allocated to electrical apparatus derived from a system of classification according to the maximum surface temperature of the apparatus.

3.11 Apparatus Group and Sub-Group

Group or sub-group assigned to apparatus depending on its suitability for use with specific gases.

An apparatus group or sub-group may be used with flammable materials of a lesser risk sub-group subject only to considerations of temperature and chemical compatibility.

3.12 Protection

3.12.1 *Type of Protection*

The measures applied in the construction of apparatus or part of apparatus to prevent ignition of surrounding explosive atmosphere by such apparatus.

NOTE — Formerly it was common for an individual item of apparatus to employ one type of protection only; increasingly apparatus may now employ two or more types of protection. Thus a rotating machine may incorporate a motor carcase in type of protection 'd' (flameproof enclosure) and a terminal box in type of protection 'e' (increased safety). It has become common usage to refer to 'explosion-protected' apparatus rather than to any one type of protection (*see also* Section 2).

3.12.2 *Enclosure Protection*

The measures applied to the enclosures of apparatus to provide degrees of protection for :

a) persons against contact with live or moving parts inside the enclosure and protection for the apparatus against ingress of solid foreign bodies;

b) the apparatus against the ingress of liquids.

3.12.3 *Electrical Protection*

The measures applied to circuits to control the effects of overload and overcurrent.

4 STATUTORY REQUIREMENTS

All electrical installations in hazardous areas have to comply with all relevant statutory requirements. The statutory authorities for industrial installations in India are as follows:

a) The Directorate General Factory Advice and Labour Institute, Bombay.

b) The Controllerate of Explosives, Nagpur.

5 CLASSIFICATION OF HAZARDOUS AREAS

This code of practice is based on the concept of dealing with the risk of fire and explosion by area classification. This concept recognizes the differing degrees of probability with which concentrations of flammable gas or vapour may arise in installations in terms of both the frequency of occurrence and the probable duration of existence on each occasion.

The detailed considerations that should be taken into account in area classification are described in IS 5572 (Part 1) : 1978. For completeness, the definitions appropriate to area classification are repeated here.

Zone 0	Zone in which an explosive gas-air mixture is continuously present, or present for long periods.
Zone 1	Zone in which an explosive gas-air mixture is likely to occur in normal operation.
Zone 2	Zone in which an explosive gas-air mixture is not likely to occur in normal operation, and if it occurs it will exist only for a short time.

It should be noted that this area classification deals only with risks due to flammable gases and vapours and, by implication, flammable mists. In a non-hazardous area normal electrical techniques apply.

When the hazardous areas of a plant have been classified, the remainder will be defined as non-hazardous.

6 TYPES OF PROTECTION

There are at present eight accepted types of protection for electrical apparatus for use in hazardous areas. A description of each type is given in Table 1. The relevant equipment specifications, where they exist, should be referred to for precise definitions of the type of protection.

Table 1 Types of Protection

Type of Protection	Title	Description	Reference to Indian Standards
'd'	Flameproof	A method of protection where the enclosure for electrical apparatus will withstand an internal explosion of the flammable gas or vapour (for which it is designed) which may enter it, without suffering damage and without communicating the internal flammation to the external flammable gas or vapour for which it is designed, through any joints or structural openings in the enclosure.	IS 2148 : 1981
'i'	Intrinsically safe apparatus or system	A protection technique based upon the restriction of electrical energy within apparatus and in the interconnecting wiring, exposed to a potentially explosive atmosphere, to a level below that which can cause ignition by either sparking or heating effects. Because of the method by which intrinsic safety is achieved it is necessary that not only the electrical apparatus exposed to the potentially explosive atmosphere but also other (associated) electrical apparatus with which it is interconnected is suitably constructed.	IS 5780 : 1980
'p'	Pressurization continuous dilution and pressurised rooms	A method of protection using the pressure of a protective gas to prevent the ingress of an external flammable atmosphere to a space which may contain a source of ignition and, where necessary, using continuous dilution of an atmosphere within a space which contains a source of emission of gas which may form an explosive atmosphere.	IS 7389 (Part 1) : 1976
'e'	Increased safety	A method of protection by which additional measures are applied to an electrical apparatus to give increased security against the possibility of excessive temperatures and of the occurrence of arcs and sparks during the service life of the apparatus. It applies only to an electrical apparatus, no parts of which produce sparks or arcs or exceed the limiting temperature in normal service.	IS 6381 : 1972
'n'	Type of protection n	A type of protection applied to an electrical apparatus such that, in normal operation, it is not capable of igniting a surrounding explosive atmosphere, and a fault capable of causing ignition is not likely to occur.	IS 8289 : 1976
's'	Special protection	A concept for those types of electrical apparatus that, by their nature, do not comply with the constructional or other requirements specified for apparatus with established types of protection, but which nevertheless can be shown, where necessary by test, to be suitable for use in hazardous areas in prescribed zones.	
'o'	Oil-immersed	A method of protection where electrical apparatus is made safe by oil-immersion in the sense that flammable gases or vapours above the oil or outside the enclosure will not be ignited.	IS 7693 : 1975
'q'	Sand-filled	A method of protection where the enclosure of electrical apparatus is filled with a mass of powdery material such that, if an arc occurs, the arc will not be liable to ignite the outer flammable atmosphere.	IS 7724 : 1975

NOTE — Other types of protection are under consideration internationally. These may include type of protection 'h' hermetically sealed and type of protection 'm' encapsulation.

7 LIGHT METALS AS CONSTRUCTIONAL MATERIALS

7.1 Particular consideration should be given to the location of an apparatus that incorporates light metals in the construction of its enclosure. The propensity of such materials to give rise to sparking that is incentive under conditions of frictional contact has been well established. Reference should be made to Annex C for further detailed guidance.

Section 2 Selection of Apparatus

8 PROCEDURE FOR SELECTING ELECTRICAL APPARATUS

8.1 General

Hazardous area apparatus should be selected for use in accordance with each of the following criteria as appropriate:

a) classification of area;
b) temperature classification;
c) apparatus sub-grouping;
d) environmental conditions.

Selection procedures according to the above criteria are recommended in **8.2** to **8.5**.

Special considerations may be required for a non-hazardous area apparatus that is associated with hazardous area apparatus (*see* appropriate Indian Standards for intrinsic safety and increased safety apparatus, respectively).

8.2 Selection According to Classification of Area

Reference should be to IS 5572 (Part 1) : 1978 for details of area classification which results in the division of the hazardous area into one or more zones.

8.2.1 Having established the zones, the types of protection to be applied to the electrical apparatus should be selected in accordance with Tables 2A and 2B.

Table 2A Selection of Apparatus According to Zone of Risk

Zone	Type of Protection	Reference to IS
0	'ia'	IS 5780 : 1980
1	Any explosion protection suitable for Zone 0 and	
	'd'	IS 2148 : 1981
	'ib'	IS 5780 : 1980
	'o' (*see* Note 1)	IS 7693 : 1975
	'p' (*see* Table 2B)	IS 7389 (Part 1) : 1976
	'q'	IS 7724 : 1975
	's'	—
2	Any explosion protection suitable for Zones 0 or 1 and	
	'e' (*see* Note 2)	IS 6381 : 1972
	'n' (*see* Note 2)	IS 8289 : 1976
	'p' (*see* Table 2B)	IS 7389 (Part 1) : 1976

NOTES

1 Oil-immersed apparatus may be used only in case its security will not be impaired by tilting or vibration of the apparatus.

2 For outdoor installations, the apparatus with type of protection 'e' and 'n' should be used with enclosures providing at least the following degree of protection in accordance with IS 4691 : 1985:

a) IP 55 where there are uninsulated conducting parts internally, and

b) IP 44 for insulated parts.

3 A substantial saving in cost may be achieved by using apparatus with type of protection 'n' in Zone 2 areas.

Table 2B Minimum Actions of Failure of Protective Gas for Type of Protection 'p'
(*Clause* 8.2.1)

Area Classification	Enclosure Does not Contain Ignition-Capable Apparatus	Enclosure Contains Ignition-Capable Apparatus
Zone 1	Alarm	Alarm and switch off
Zone 2	No action required	Alarm

8.3 Selection According to Temperature Classification

When selecting apparatus according to temperature classification, the maximum surface temperature of the T class of the apparatus (or, where the apparatus is marked with a particular maximum surface temperature, that temperature) should not exceed the ignition temperature of the gases or vapours involved.

8.3.1 In certain cases, temperatures higher than that of the marked temperature class can be permitted, for example, for small components such as transistors or resistors, provided it is proved by tests or other experimental evidence that there is no risk of direct or indirect flammation, deterioration or deformation by such high temperatures.

8.3.2 A T class is assigned to apparatus on the basis of temperature rise tests assuming that the apparatus may be used in an environment with an ambient temperature not exceeding 40°C. In special cases, apparatus may be designed on request to operate in an environment with a temperature of more than 40°C. In this case the designed maximum permitted temperature of the environment will be clearly marked on the apparatus. The T class will have been assigned on the basis of temperature rise tests and the assumption that the apparatus may operate at temperatures up to the designed maximum permitted temperature of the environment.

8.3.3 When apparatus, which has had a T class assigned assuming a 40°C maximum ambient temperature, is to be used at a higher environmental temperature, for example, because it is mounted on a hot surface, the maximum surface temperature of the apparatus should not exceed the ignition temperature of the gases or vapours likely to be present. It is also important to check with the manufacturer on the suitability of the apparatus to operate at these higher temperatures. For example, when apparatus is to be mounted under pipe-lagging, it is virtually unaffected by the air temperature, but may fail due to heat from the pipe.

8.3.4 The permitted maximum surface temperatures classified according to IS 13346 : 1992 are given in Table 3.

Table 3 Relationship Between T Class and Maximum Surface Temperature

T Class	Maximum Surface Temperature °C
T1	450
T2	300
T3	200
T4	135
T5	100
T6	85

8.3.5 An example can be given of the relationship between T class and ignition temperature. Cyclohexane has an ignition temperature of 259°C and, therefore, assuming a maximum environmental temperature of 40°C, apparatus with a temperature class T2 (that is, 300°C) would not be suitable whereas apparatus with a temperature class of T3 (that is 200°C) would be suitable.

NOTE – In special cases, apparatus can be marked with a particular temperature as well as one of the six T classes. For example, in the case cited above if the apparatus were marked with a temperature of 259°C, as well as the temperature class of T2, it would still be suitable for use in areas where a potentially explosive atmosphere of cyclohexane might form.

8.4 Selection According to Apparatus Sub-Grouping

In the new groupings, agreed internationally, Group I is reserved for apparatus for mines susceptible to methane (firedamp) and is therefore outside the scope of this standard. Group II is reserved for apparatus for use in all other places where there may be potentially explosive atmospheres and as appropriate is sub-grouped IIA, IIB and IIC.

8.4.1 It should be noted that apparatus sub-grouping is applied to the technique of prevention of flame transmission and limitation of energy. Apparatus with type of protection 's' may be subject to sub-grouping where it used one or more of these techniques. The protective features of other types of protection apply equally to all industrial gases, subject only to temperature classification; apparatus sub-grouping is not therefore necessary (*see also* Section 6).

8.4.2 Apparatus may be protected by one or more types of protection which may require apparatus sub-grouping. Such apparatus will be marked as described in 41.4. In these circumstances, the apparatus should be selected according to the apparatus sub-group to which the flammable materials that may be present are allocated.

8.4.3 Apparatus should be used only with materials allocated to the appropriate apparatus sub-group, as indicated in Table 6 (*see* Annex D), whose ignition temperatures are not less than the maximum temperature of the T class certified for the apparatus. Apparatus certified for a particular sub-group may also be used with materials allocated to a lower risk sub-group, subject again to considerations of temperature classification.

8.4.4 It will sometimes be found necessary to use electrical apparatus in applications where materials may be present that have not yet been allocated to a sub-group. In these circumstances, expert advice should be obtained on the sub-group allocation of the materials in question.

NOTE – In IS 2148 : 1981 and IS 9570 : 1980 flammable gases and vapours are grouped or classified, respectively, according to the experimental data for limiting safe gaps or igniting currents measured under precisely specified conditions. In the case of IS 9570 : 1980 many materials are classified according to their chemical similarity with gases and vapours that are already classified on the basis of experimental data. Neither method of grouping takes into account the need for surface temperature classification, since ignition temperatures generally are not related to other combustion characteristics. It is therefore inaccurate to assume that any particular apparatus complying with the design requirements for a group of gases could be used safely with all materials allocated to that group. For this reason, instead of grouping gases, an apparatus itself is now grouped according to design criteria specified in the appropriate Indian Standards such as IS 6381 : 1972 and IS 8289 : 1976.

8.5 Selection According to Environmental Conditions

Apparatus and its component parts should be constructed so as to guard against electrical and mechanical failure in the intended conditions of use. The integrity of some electrical apparatus may be effected when required to operate under temperature or pressure conditions outside those for which the apparatus has been constructed. In such conditions further advice should be sought.

8.5.1 Particular attention should be given to the need for protection against the weather, the ingress of liquids and particulate matter, corrosion, the effect of solvents and the effect of heat from adjacent plant (*see also* **28.3** to **28.5**).

9 INTERCONNECTION OF APPARATUS

The safety of individual pieces of apparatus may be influenced by any other apparatus with which it is interconnected. For such system considerations, reference should be made to appropriate standards covering individual protection concepts.

Section 3 General Installation Recommendations

10 GENERAL

10.1 In addition to any recommendations there may be for installation in non-hazardous areas, further recommendations for installations in hazardous areas as a consequence of the nature of the environment and that are generally applicable to all types of protection are described in **11** to **21**.

10.2 The explosion protection of some installations, for example, those using electric surface heating, pressurization 'p', etc, is dependent on the overall design of the finished system. In such cases, the appropriate design codes or standards should be used for guidance to carry out the installation (*see* **B-3**).

10.3 Alterations to apparatus or systems may invalidate any certificate or other documentation relating to that apparatus or system. Such alterations should be made only with the agreement of the occupier in consultation with the manufacturer where appropriate.

10.4 There may be special requirements listed in the certification documents (*see* **41.2**) that will affect the method of installation. Installers and occupiers should satisfy themselves that such conditions are properly met.

11 ACCESS FOR INSPECTION

Installations should be designed and the apparatus and materials installed with a view to providing ease of access for inspection and maintenance.

12 PLANS AND RECORDS

For each site a responsible person should maintain and make available plans or records of the following items:

a) the classification and extent of hazardous areas together with the other information as recommended in IS 5572 (Part 1) : 1978;

b) records sufficient to enable the explosion protected equipment to be maintained in accordance with its type of protection; and

c) the type, route and details of underground cables.

13 ELECTRICAL RATINGS

13.1 Electrical apparatus and materials should be installed, used and maintained within their electrical ratings for power, voltage, current, frequency, duty and such other characteristics where non-compliance might jeopardize the safety of the installation.

13.2 In respect of electrical apparatus from overseas suppliers, because of the differing nature of the supply networks, special care should be taken that:

a) the voltage and frequency rating are appropriate to the supply system on which the apparatus is to be used; and

b) the temperature classification has been established for the correct voltage, frequency, etc.

14 INSTALLATION OF APPARATUS

14.1 All apparatus should be installed with due regard to the possibility of external mechanical damage affecting the type of protection of the apparatus. Where equipment is to be installed in areas of high mechanical risk, additional measures such as the provision of guards for light transmitting parts, may be necessary. However, additional measures should not impair the integrity of the type of protection.

14.2 Special installation conditions apply to any type of certified explosion protected apparatus where the certificate number has a suffix marking of 'B' or 'X' The certification documents should be studied to ascertain the conditions of installation. The manufacturers should also have provided clear installation instructions.

15 INTEGRITY OF INSULATION

Care should be taken during installation to maintain the degree of electrical insulation provided by the construction of the apparatus so that the possibility of accidental sparking or arching is avoided.

16 AUTOMATIC OVERCURRENT PROTECTION

In general, all circuits and apparatus in hazardous areas should be provided with automatic means of disconnection in the event of overcurrent (short circuit and overload) conditions. However, apparatus with particular types of protection,may have additional and/or alternative requirements, and reference should be made to the recommendations in the appropriate Indian Standard. Suitable protection should be fitted where there is a danger that three-phase apparatus may be subjected to excess current during single-phase operation.

17 EARTHING AND EARTH FAULT PROTECTION

17.1 Earthing of Power Systems

Generally earthing of power distribution systems should be in accordance with the recommendations of IS 3043 : 1987.

In typical industrial systems, for example 415 V and 440 V, earth fault protection may be afforded by the overcurrent protective devices. However, where the earth loop impedance is too high for that method to be adopted, it will be necessary to provide earth fault protection by other means such as residual current devices. Smaller rating systems do not require residual current devices.

In higher voltage systems, for example, 3.3 kV and 6.6 kV, apparatus should have earth fault protection in addition to overcurrent protection.

If environmental conditions could lead to accelerated degradation of earth loop paths, anti-corrosive protection should be provided or the earth loop impedance values decreased accordingly.

17.2 Earthing of Intrinsically Safe Electrical Systems/Apparatus 'i'

Detailed recommendations will be covered later in a separate standard.

17.3 Lightning Protection

Recommendations for lightning protection are given in IS 2309 : 1969.

17.4 Electrostatic Phenomena

Recommendations for the avoidance of ignition risks due to static electricity are given in IS 7689 : 1989.

17.5 Cathodic Protection

Recommendations for cathodic protection systems are given in IS 8062 (Part 1) : 1976.

17.6 Protective Multiple Earthing (PME)

Where the power supply is directly from a system that is protected by PME, special precautions may be required within the hazardous area and specialist advice should be sought.

17.7 Interconnection of Earthing Systems

The power, lightning, and static earthing systems, where they exist in the same area, should be effectively connected together to ensure as far as possible that all metal work in a particular area is at the same potential under all conditions.

18 ISOLATION

18.1 At a suitable point or points outside the hazardous area there should be single or multiple means of isolating mains supplies to the hazardous area.

18.2 A means of isolation of each circuit or group of circuits, to include isolation of the neutral, should be provided. Where the means of isolation is located inside the hazardous area it should be provided with an appropriate type of protection.

18.3 Labelling should be provided immediately adjacent to each means of isolation to permit rapid identification of the circuit or group of circuits thereby controlled. There should be effective measures to prevent the restoration of supply to the apparatus whilst the risk of exposing live conductors to an explosive atmosphere continues.

19 EMERGENCY SUPPLIES

Special precautions should be taken in the provision of emergency supplies to electrical apparatus (for example emergency lighting, critical instruments, valves) that may be required to operate during periods of power failure.

20 WIRING SYSTEMS

20.1 General

The types of wiring that in principle may be used for installations in hazardous areas are described in this clause. The detailed recommendations for permitted types of cable and their accessories are described in IS 5571 : 1979.

For a Zone 0 installation, cabling will be either part of an 'ia' systems or as recommended for type of protection 's' for Zone 0.

Types of wiring and systems that should be used in Zone 1 and 2 areas are:

a) cables drawn into screwed, solid drawn or seam welded steel conduit; and

b) cables that are otherwise suitably protected against mechanical damage.

NOTE — The sheath of a metal sheathed cable should not be used as the neutral conductor.

Examples of the types of cable which are in accordance with the recommendations of (b) are:

1) thermoplastic or elastomer insulated screened or armoured cable without a load sheath and with polyvinylchloride (PVC) polychroprene (PCP) or similar sheath overall;
2) cables enclosed in a seamless aluminium sheath with or without armour, with an outer protective sheath (*see also* Annex C);
3) mineral insulated metal sheathed cable (*see also* Annex C);
4) thermoplastic or elastomer insulated flexible cable or cord with a flexible metallic screen or armour and a PVC, PCP or similar sheath overall; and
5) thermoplastic insulated cable with semi-rigid sheath.

For type of protection '1' (intrinsic safety) and for apparatus used in Zone 2 only, other cables may be used.

20.2 General Installation Recommendations for Wiring Systems

20.2.1 The wiring entry to the apparatus should maintain the integrity of the type of protection of the apparatus.

20.2.2 Unused cable entries in electrical apparatus should be closed with plugs suitable for the type of protection of the apparatus.

20.2.3 Where accessories (for example, a junction box) are used for the interconnection of cable, only those accessories that are suitable for the zone concerned should be used.

20.2.4 Electrical continuity between metallic enclosures and conduit, armour or cable sheaths and armour, or across any joints in the coduit or armour, should be maintained by the integrity of the joint itself. If external bonding is in certain circumstances necessary, it should preferably be connected directly across the joint.

20.2.5 Where circuits traverse a hazardous area in passing from one non-hazardous area to another, the wiring in the hazardous area should be in accordance with the recommendations of this code.

20.2.6 Except for trace heating, fortuitous contact between conduit or the metallic armouring/sheathing of cables and pipe work or equipment containing flammable gases, vapour or liquids should be avoided. The insulation provided by a non-metallic outer sheath on a cable will usually be sufficient to avoid this.

20.2.7 Wiring should be installed, so far as is practicable, in positions that will prevent its being exposed to mechanical damages and (with the exception of trace heating cables) to the effects of heat and to corrosive or solvent agencies. Where exposure of this nature is unavoidable, appropriate protective measures should be taken.

20.2.8 All apparatus connections and wiring whose functions are not immediately apparent should be clearly marked to enable their relationship to any associated apparatus, connections and wiring to be clearly recognized.

20.2.9 Where cables or conduit pass through a floor, wall, partition or ceiling that forms a gas or fire barrier, the hole provided for them should be made good with cement or similar incombustible material to the full thickness of the floor, wall, partition or ceiling. Alternatively, cable glands or cable transits may be used for this purpose.

20.2.10 Where trunking, ducts, pipes or trenches are used to accommodate cables, precautions should be taken to prevent the passage of flammable gases, vapours or liquids from one area to another and to prevent the collection of flammable gases, vapours or liquids in trenches. Such precautions may involve the sealing of trunking, ducts and pipes and the adequate ventilation or sand filling of trenches.

20.2.11 For terminal connections to fixed apparatus that may be required to be moved a small distance (for example, motors on slids rails), cables arranged to permit the necessary movement without detriment to the cable, or one of the types of cable suitable for transportable apparatus may be used. If flexible conduit is used, it and its fittings should be so constructed and assembled that damage to the cable consequent upon its use is avoided. Adequate earthing or bonding should be maintained other than by means of the flexible conduit.

20.2.12 Where an overhead line provides power or telecommunication services to apparatus in a hazardous area it should be terminated in a non-hazardous area and the service continued by cable. Suitable surge protection apparatus should be fitted at or near the terminal point. The armouring or metal sheathing of the cable should be electrically continuous, and the end adjacent to the point of connection with the overhead line should be bonded to the earth electrode of the surge protection apparatus. In addition the armouring or metal sheathing should be independently earthed as near as possible to the lighting protective system, if any, associated with the hazardous area (*see* IS 2309 : 1969).

20.3 Environmental Factors Affecting Choice of Wiring System

20.3.1 Insulating materials may be attacked by certain chemicals, and where contact may be sufficiently long that deterioration could result from such exposure, then consideration should be given to the use of a protective sheath.

20.3.2 Where cables may be subjected to excessive flexing, consideration should be given to the avoidance of fracture, for example, when using mineral insulated cable, by forming the cable into a loop close to the point of termination.

20.3.3 Where electrolytic corrosion of metal sheath may result from contact with walls or other surfaces to which the cable is attached, it should be kept clear of such surfaces or covered with a protective sheath.

20.4 Conduit Systems

Where used, screwed heavy gauge steel conduit, solid drawn or seam welded, should be in accordance with the requirements of IS 9537 (Part 2) : 1981.

Such screwed steel conduit systems are satisfactory for many situations but should not be used where vibration may cause fracture or loosening of joints or where excessive stress may be imposed as a result of its rigidity of where corrosion or excessive internal condensation of moisture is likely to occur. In such circumstances, flexible conduit of very heavy mechanical strength should be used.

Where a run of conduit, irrespective of size, passes from a hazardous area to a non-hazardous area, a stopper box or sealing device should be inserted at the hazardous area boundary or, failing this, on the side remote from the hazardous area.

NOTE — The use of a sealing device is essential to the maintenance of certain types of protection.

Elbows of the solid types may be used for the immediate connection of conduit to apparatus.

Surface mounted conduit should be supported by spacing saddles.

All joints in an assembly of conduit should be prepared before or after assembly so that the development of rust is inhibited and earth continuity and bonding is maintained.

All bends in conduit should be machine-made and rounded so as to facilitate drawing in of cables.

For additional requirements for conduit systems that are relevant to particular types of protection, appropriate standards may be referred to.

20.5 Cable Systems

20.5.1 *General*

Conductors may be copper or aluminium but plain aluminium should not be used for conductors with cross-sectional areas less than 16 mm^2 (*see also* C-7 for precautions on the use of aluminium in Ex 'd' flameproof enclosures).

Cable runs should, where practicable, be uninterrupted. Where discontinuities cannot be avoided, the joint should be encapsulated or made in a compound-filled joint box or be protected in accordance with the requirements of the zone.

Certain types of protection require specific types of cable glands. Compression type glands would serve the purpose as the cables would be terminated in a terminal box. Direct entry without a terminal box shall be treated as a special case.

Attention is drawn to the need to prevent transmission of flammable liquids or gases from a hazardous to a non-hazardous area through the interstices of cables terminating in apparatus (for example pressure switches or canned pumps) into which such fluids are introduced. Under fault conditions (for example, diaphragm or can failure) the fluid may be released inside the apparatus under considerable pressure against whose effects it may be difficult to seal the cable interstices. Apparatus of this kind should be deliberately vented to atmosphere, but if this is not possible (for example, a type 'd' enclosure) a special sealing joint or length of mineral insulated metal sheathed cable should be introduced in the cable run.

All cables should be provided with adequate mechanical protection. Cables should be adequately supported throughout their length, care being taken to avoid excessive pressure when cleats are used. Horizontal cables may be carried on support or cable trays or through protective troughs or tubes. Rising cables should be clipped, cleated or otherwise attached to suitable supports that provide adequate mechanical protection and support.

Where single core metal sheathed or armoured cables are used, precautions should be taken to avoid dangerous sheath voltages or currents.

20.5.2 *PVC Covered and/or Insulated Cables*

Attention is drawn to the fact that as the temperature decreases, PVC becomes increasingly stiff and brittle with the result that, if PVC cables are bent too sharply or are struck at temperatures of about 0°C or lower, there is a risk for most PVC cables of shattering the PVC. Therefore, it is advisable to store PVC cable at temperatures above 0°C for at least 24 h prior to installation (*see* **20.3.1**).

20.5.3 *Paper Insulated Cables*

Where paper insulated armoured cables are used, and particularly where such cables may be exposed to high temperature, preference should be given to non-draining cable. In the case of other types of paper insulated armoured cables, vertical runs should be avoided.

Cable boxes should, if necessary, be arranged for sealing the cable insulation and should be provided, as necessary, with adequate means for ensuring the earth continuity of metallic sheath and/or armour.

Adequate arrangements should be made to ensure that cable boxes can be completely filled with the necessary compound or insulating oil according to their design.

20.5.4 *Mineral Insulated Metal Sheathed Cables*

Cable terminations should incorporate a seal for the cable insulation and, where necessary, means of ensuring adequate earth continuity.

NOTE — Certain types of protection require specific types of seal.

Seals in which compound is used should not be exposed to temperature that may, in the course of normal working, affect the satisfactory functioning of such compound.

Where there is a risk of mineral insulated cables being exposed to excessive voltages such as inductive surges, surge suppression should be fitted. Where surge suppression devices are installed in hazardous areas, they should be suitably exposition protected.

20.5.5 *Aluminium Sheathed Cables*

Aluminium sheathed cables, unless sheath with a protective covering, should not be installed in contact with walls or floors. Consideration should be given to the avoidance of frictional contact with such cables (*see* Annex C).

21 PORTABLE AND TRANSPORTABLE APPARATUS AND ITS CONNECTIONS

Apparatus other than fixed apparatus should have a type of protection appropriate to the zone(s) of use. During use such apparatus should not be transferred from a zone of lower risk to a zone of higher risk unless it is suitably protected for the higher risk. Additionally, the apparatus group and T class should be appropriate to all of the gases and vapours in which the apparatus may be used.

NOTE — Ordinary industrial portable or transportable apparatus, welding equipment, etc, should not be used in a hazardous area unless its use is undertaken under a controlled procedure and the specific location has been assessed to ensure that potentially flammable gas or vapour is absent.

Should plugs and sockets be in a hazardous area, they should be suitable for use in the particular zone of risk and should have mechanical and/or electrical interlocking to prevent danger during insertion or removal of the plug.

In many cases the type of cable to be used will be stated on the apparatus certificate. In cases where this is not so, the cable should be suitable for rough usage and other adverse environmental conditions (for example, elevated temperatures, presence of solvents). It should also be suitable for the circuit protective arrangements (for example, where earth monitoring is used, the necessary number of conductors should be included). Where the apparatus needs to be earthed, the cable may include an angular earthed flexible metallic screen in addition to the earth conductor.

Section 4 Inspection, Maintenance and Testing

22 GENERAL

22.1 To minimize the risk of ignition of an explosive atmosphere by electrical apparatus, efficient inspection, maintenance and testing of the apparatus, systems and installations are essential. It should be noted that correct functional operation does not itself indicate conformity with the recommendations for the safe use of apparatus. The general recommendations for inspection, maintenance and testing that are applicable to all types of protection are described in 23 to 28.

23 PERSONNEL

23.1 The inspection, testing, maintenance, replacement and repair of apparatus, systems and installations should be carried out only by persons whose training includes instruction on the various types of protection involved. Appropriate refresher training should be given from time to time.

24 ISOLATION OF APPARATUS

24.1 No apparatus should be opened in a hazardous area other than apparatus with type of protection 'i' (intrinsic safety) and non-incendive apparatus until it has been disconnected from its source of supply (*see* 18) and effective measures, such as the locking of the disconnector in the open position or fuse removal, have been taken to prevent its being made alive before re-assembly. Particular attention should be paid in the case of an apparatus that may be live even after it has been disconnected from a source of supply. Where heavy rotating machinery is involved, the back e.m.f. of such plant should be considered and precautions will usually need to be taken to ensure that the apparatus, or any apparatus associated with it, is not opened until the rotating plant is stationary. Most power capacitors are fitted with discharge resistors and it should be noted that these take a finite time to bring the terminal voltage to a harmless value.

24.2 Where for purpose cf electrical testing it is essential to restore the supply before the apparatus is reassembled, then this work would be under a controlled procedure and the specific location assessed to ensure that potentially flammable gas or vapour is absent. For the testing of intrinsically safe electrical apparatus and systems *see* IS 5780 : 1980.

25 PRECAUTIONS CONCERNING THE USE OF IGNITING AGENCIES

25.1 No operation involving the use of an open flame or other source of ignition should be attempted in a hazardous area until the conditions have been made safe by the control of the flammable material that may give rise to the risk. Such operations should be undertaken only on the issue of a gas free certificate, confirming that adequate control measures have been taken and that tests have been made and will be repeated at sufficiently frequent intervals to ensure that safe conditions are maintained.

26 INITIAL AND PERIODIC INSPECTIONS

26.1 All electrical apparatus, systems and installations should be inspected prior to commissioning to check that the selection and installation is appropriate and in accordance with IS 5571 : 1979. Examples of some of the items which should be included in an initial inspection are given in Table 4.

26.2 Following any replacement, repair, modification or adjustment, the items concerned should be inspected, to check that the appropriate recommendations of the code have been maintained.

26.3 If at any time there is a change in the area classification or in the characteristic of the flammable material used in the area, or if any apparatus is moved from one location to another, a check should be made to ensure that the type of protection, apparatus group and T class, where appropriate, are suitable for the revised conditions.

26.4 The extent, complexity and freuqency of inspection of apparatus, systems and installations when in use should be determined by those whose training and experience will enable them to recognize any potential hazards and who are familiar with the local environmental conditions and use.

26.5 The frequency of inspection depends on the type of equipment, the factors governing its deterioration, and the finding of previous inspections. Examples of factors which can affect the deterioration of apparatus or otherwise lead to an unsafe condition are given in Table 5.

26.6 It is, therefore, recommended that once the apparatus has been taken into use, initial intervals between inspections should be of a reasonably short duration and that a system be established to enable subsequent inspection intervals to be reviewed and modified in the light of operational experience. Where inspection intervals and methods are already established and are found by experience to be satisfactory for similar apparatus and environments, these may continue to be used. It is recommended that an inspection record system be operated so that the review of inspection frequencies is effective.

26.7 When large number of similar items such as luminaires, junction boxes, etc, are installed, it may be feasible to carry out inspections on a sample basis provided that the degree of sampling in addition to the inspection frequency is subjected to review.

Table 4 Example of Schedule for Initial Inspection
(*Clause* 26.1)

Initial Inspection Items
Apparatus appropriate for the area classification
Correct temperature classification
Appropriate apparatus group or sub-group
Correct circuit identification
Maintenance of integrity of enclosure
Cable entries and stoppers, etc, are complete
Electrical connections are tight
Satisfactory earthing
Correct rating of apparatus and components
Damage to installation
Adequate environmental protection (e.g. against weather, mechanical damage)
No unauthorized modifications

NOTE — Items are not listed in any order of priority. Where integrity of type of protection is dependent on electrical protection, this should be checked initially.

Table 5 Example of Schedule for Subsequent Inspections
(*Clause* 26.5)

Factors Affecting Integrity of Apparatus, Systems and Installations
Corrosion of enclosures, fixings, cable entries, etc
Undue accumulation of dust and dirt
Loose electrical connections including those for earthing
Loose fixings, glands, conduit, stoppers, etc
Condition of enclosure gaskets and fastenings
Leakage of oil or compound
Condition of bearings
Inadvertent contact between rotating and fixed parts
Integrity of guards
Incorrect lamp ratings or type
Undue vibration
Malfunction of relays and protective devices
Unauthorized modifications or adjustments
Inappropriate maintenance, e.g. not in accordance with manufacturer's recommendations

NOTE — Items are not listed in any order of priority. Where integrity of type of protection is dependent on electrical protection, this should be checked initially.

27 INITIAL AND PERIODIC TESTING

27.1 All electrical apparatus, systems and installations should be tested prior to commissioning and these tests should include the following:

a) insulation resistance measurement;

b) earth electrode resistance measurement;

c) earth loop impedance measurement; and

NOTE — It may be advantageous to make the earth loop impedance measurement with both a substantial current and with an intrinsically safe tester to enable the measurement to be made with the intrinsically safe tester alone for subsequent tests and to allow those results to be compared with the initial test results. It should be noted that tests made with an intrinsically safe tester may not necessarily identify certain bad connections because of the low test current.

d) operation and setting of protective devices.

The results of all tests should be recorded and included in the record of inspections described in **26**.

27.2 The testing of apparatus, systems and installations when in use should be carried out by those whose experience will enable them to recognize the potential hazards and who are familiar with local environmental conditions and use.

27.3 Test procedures should be designed to cause the minimum disturbance to the installation or system.

27.4 Diagnostic testing and recording of results of such functions as time, operating voltage, circuit resistance, insulation resistance, etc, should be used where possible to show trends in electrical condition and to aid the determination of both the nature and frequency of subsequent tests and inspections.

27.5 The frequency of testing depends on the type of equipment or system, the factors governing its deterioration and in particular the finds of previous tests. Factors which may affect the deterioration of apparatus are identified in Table 6 and as these should be taken into account in determining the frequency of inspection, the frequency of testing will not be greater than, and in fact may be less than, the frequency of inspection for the relevant apparatus or system. The frequency of testing should be established and reviewed in a manner similar to that recommended for the inspection.

27.6 Testing in continuously operating plant and on similar apparatus or systems may be undertaken on a sample basis subject to review similar to that recommended for inspections conducted on a sample basis.

27.7 Tests should be made in such a way that the safety devices used in low energy or low voltage apparatus and circuits are not subject to damage by excess voltage. For testing intrinsically safe electrical systems 'i' *see* IS 5780 : 1980.

27.8 Test should be undertaken under a controlled procedure to ensure that the specific location has either been assessed for the absence of a flammable gas or vapour or that the test method is non-incendive.

28 MAINTENANCE RECOMMENDATIONS

28.1 Alterations to Apparatus

The general condition of all apparatus should be noted periodically as recommended in **26** and appropriate remedial measures should be taken where necessary. Care should be taken, however, to maintain the integrity of the type of protection provided for the apparatus; this may require consultation with the original manufacturer. Replacement parts should be in accordance with the conditions of certification. No alteration that might invalidate the certificate or other document relating to the safety of apparatus should be made to any apparatus without appropriate approval.

28.2 Maintenance of Flexible Cables

Flexible cables, flexible conduits and their terminations should be inspected at regular intervals and should be replaced if found to be damaged or defective.

28.3 Precautions Against Corrosion

Metallic enclosures of apparatus should where necessary, be treated with an appropriate protective coating as a precaution against corrosion, the frequency and nature of such treatment being determined by the environmental conditions.

NOTE — For special precautions concerning the use of certain protective materials (e.g. on the flange faces of Ex 'd' flameproof apparatus) reference should be made to IS 2148 : 1981.

28.4 Cleanliness

All parts of installations should be kept clean and free from accumulations of dust and deleterious substances.

28.5 Precautions Against Excessive Temperature Rise

Apparatus should be kept of free from dust deposits of such a nature as could cause excessive rise in temperature.

When replacing lamps in luminaires the correct rating and type should be used for excessive temperature rise may result.

The etching, painting or screening of light transmitting parts may lead to excessive temperatures.

28.6 Withdrawal from Service

Should it be necessary for maintenance purposes to withdraw apparatus, etc, from service, the exposed conductors should be terminated in an appropriate certified enclosure; alternatively, the cable may be protected adequately by insulating the ends of the conductors and isolating the cable from all sources of power supply. Should the apparatus be permanently withdrawn from service, associated wiring should be removed or, alternatively, otherwise correctly terminated in an appropriate certified enclosure.

28.7 Fastenings and Tools

Where special bolts and other fastenings or special tools are required, these items should be available and should be used.

Section 5 Properties of Flammable Liquids, Vapours and Gases

29 GENERAL

29.1 Available data applicable only to the use of electrical apparatus in hazardous areas are given in Table 6 (*see* Annex D) for those flammable gases and vapours that have been allocated to apparatus groups. The physical properties of these materials that have to be considered when the degree of risk appropriate to a particular application or installation is being assessed are defined and discussed in 30 to 36 in the same order as that in which they are given in Table 6 [*see also* IS 5572 (Part 1) : 1978].

29.2 Properties of the materials given in Table 6 are generally for materials in the pure form and may be different if there are impurities or where there are mixtures of materials. In such cases expert advice should be sought. For descriptions of the concepts of temperature classification and apparatus grouping, *see* 8.3 and 8.4.

30 MELTING POINT AND BOILING POINT

30.1 The melting and boiling points have their usual meanings, and the data listed in Table 6 apply at standard atmospheric pressure.

31 RELATIVE VAPOUR DENSITY

31.1 The relative vapour density of a material is the mass of a given volume of the material in its gaseous or vapour form compared with the mass of an equal volume of dry air at the same temperature and pressure. It is often calculated as the ratio of the relative molecular mass of the material to the average relative molecular mass of air (the value of the latter being approximately 29).

32 FLASH POINT

32.1 General

The flash point of a material is the minimum temperature at which it gives off sufficient vapour to form a flammable mixture with air near the surface of the material or within the apparatus used for flash point determination.

32.1.1 Flash point data are normally associated with materials in the liquid phase. There are a few materials, however, that give off sufficient vapour in the solid phase to form flammable mixtures with air. For those materials and those that sublimate (i.e. pass from solid to vapour without the normal intermediate liquid phase), flash point data will be associated with the materials in their solid form.

32.1.2 The test apparatus used for the measurement of flash point is normally one of two types, of which there are several variants. These are called generally open cup and closed cup flash point testers. For most liquids the flash point determined by the closed cup method is slightly lower (in the region of 5 % to 10 % when measured in °C) than that determined by the open cup method. Flash points measured by the more sensitive closed cup method are, therefore, normally used and are given in Table 6.

32.2 Materials having High Flash Points

Some materials have such high flash points that they do not form flammable mixtures with air at normal ambient temperatures, even when exposed to the sun in tropical locations. These should not be discounted as ignition hazards, however, since exposure to a suitably hot surface or use of the material at a temperature above its flash point may create a flammable mixture locally, which may be ignited by the same hot surface or an alternative ignition source. It is therefore necessary to consider the limitation of surface temperatures even when materials of high flash point are being processed.

32.2.1 It should be noted also that materials having high flash points may be used in processes involving high temperatures and possibly high pressures. The normal or accidental release to the atmosphere of compounds under such conditions may present local explosion risks that would not normally be associated with high flash point materials. Materials having high flash points can form flammable mixtures with air at subatmospheric pressure.

32.3 Classification of Flash Points

In some industries, it has been found convenient to group materials into prescribed ranges of flammability according to their flash points to facilitate safe handling. In certain applications, legislation specifies the limits for these ranges.

33 LIMITS OF FLAMMABILITY

33.1 All combustible gases and vapours are characterized by flammable limits between which the gas or vapour mixed with air is capable of sustaining the propagation of flame.

33.2 The limits are called the lower flammable limit (LFL) and the upper or flammable limit (UFL) and are usually expressed as percentages of the material mixed with air by volume. They are also sometimes expressed as milligrams of material per litre of air. Where appropriate, both sets of data are included in Table 6.

34 FLAMMABILITY RANGE

34.1 The range of gas or vapour mixtures with air between the flammable limits over which the gas/air mixture is continuously flammable is called the flammability range. Gas/air mixtures outside this range are, therefore, non-flammable under normal atmospheric conditions. Concentrations above the UFL in free atmospheric conditions cannot be controlled and further dilution with air will produce mixtures within the flammability range.

35 EFFECT OF ENVIRONMENTS WITH OTHER THAN NORMAL ATMOSPHERIC CONDITIONS

35.1 It should be noted that the data given in Table 6 apply only to mixtures of flammable gases and vapours with air under normal conditions of atmospheric temperature and pressure or at suitably elevated temperatures if the flash point of the vapour is above the normal ambient temperature. Caution should be exercised therefore in assessing the explosivity of gas or vapour with air under environmental conditions that are other than normal. It is possible here to give only general guidance on the influence of changes in temperature, pressure and oxygen content of the mixture.

35.2 Generally, the effect of increased temperature of pressure is to lower the LFL and to raise the UFL. Reduction in temperature or pressure has the opposite effect.

35.3 An increase in oxygen content of a gas mixture, compared with a mixture of the flammable gas or vapour with air only, has little or no effect on the LFL but generally results in an increase UFL. The increase in the upper limit depends on the degree of oxygen enrichment and may be substantial. Thus, the effect generally of an increase in oxygen content is to broaden the flammability range.

36 IGNITION TEMPERATURE

36.1 The ignition temperature of a material is the minimum temperature under prescribed test conditions at which the material will ignite and sustain combustion when mixed with air at normal pressure, without initiation of ignition by spark or flame.

36.2 The ignition temperature, formerly known as the auto-ignition or spontaneous ignition temperature, should be clearly distinguished from the flash point. In the latter case, ignition is initiated by a small flame simply to determine that a flammable mixture exists. In the former, ignition is a consequence of chemical reactions initiated on account of the temperature of the local environment and may therefore in practice be a result of the temperature of hot surfaces adjacent to the flammable atmosphere.

36.3 The majority of ignition temperatures listed in Table 6 have been determined with the test apparatus and procedure described in IS 7820 : 1975 or with equivalent test apparatus. Where a determination by a method other than that in IS 7820 : 1975 provides the only data available, the classification may be regarded as provisional only and has been, for guidance, enclosed in parentheses in Table 6.

36.4 The direct result of established ignition temperatures is to limit the surface temperatures of electrical apparatus in hazardous areas so that these do not present an ignition risk. Formerly permitted surface temperatures were limited to a certain proportion of the measured ignition temperature (commonly 80%) to provide a factor of safety. It is now generally accepted, however, that the sensitivity of the recognized test methods is such that the temperatures of unprotected surfaces of electrical apparatus may safely be allowed to rise to the ignition temperature of the gas or vapour that presents the explosion risk. Where more than one flammable material may be present in a particular application, the surface temperature should be limited to the lowest value of the ignition temperatures of the combustibles concerned or the ignition temperature of the particular mixture as determined by test. However where there is a possibility of catalytic interaction between the components or where mixtures of hydrogen, moisture or hydrocarbons with carbon monoxide occur, the surface temperature may need to be less than the lowest ignition temperature of the individual components.

36.5 It should be noted that the value for ignition temperature is dependent on the method chosen for its measurement. In particular, factor such as the geometry, dimensions and materials of the test apparatus influence the measured ignition temperature. Care should be exercised, therefore, if the ignition temperature data contained in this standard are applied to equipment other than electrical apparatus.

37 GENERAL CONSIDERATIONS

37.1 Relation Between Ignition Temperature and Maximum Surface Temperature

The vapour given off from a flammable liquid will form a flammable mixture with air, provided the temperature of the liquid is at or above its flash point. The flammable mixture may then be ignited by one of several means: a flame, a suitable frictional spark, an electrical spark of sufficient energy or a hot surface. If, on the other hand, the local ambient temperature and that of the electrical apparatus, etc, are below the flashpoint, the vapour will eventually condense to a mist of liquid droplets and spread as such both through the atmosphere and over the surfaces of the apparatus. It is in the latter respect that adequate resistance to chemical attack may be particularly important.

37.1.1 For ignition by a hot surface, the surface temperature has generally to be greater than the ignition temperature of the flammable material. Therefore, to ensure that ignition by hot surfaces does not occur, it is necessary that the temperature of all unprotected surfaces exposed to the gas or the vapour/air mixture should not be greater than the ignition temperature. This has led to the concept of temperature classification described in 8.3.

NOTE – Surfaces that are catalytically active can ignite vapours at temperatures lower than the normal ignition temperature.

37.2 Mixtures of Materials

Single-component flammable materials are not often encountered in practice. Most frequently, mixtures of two or more materials are present, in ratios that may vary between prescribed limits. Consideration has then to be given to the characteristics required for electrical apparatus in the light of the properties of each individual component present. Often this will impose no difficulty since, by the nature of the process, the various materials will possess similar chemical properties and, often, similar combustion properties.

37.2.1 There are occasions, however, when this is not the case. The materials may be of different gas classifications or have widely different ignition temperatures. In these cases, it is possible to give only the most general of rules for guidance. In general it should be assumed that, at some time during the process or the life of the plant, the component in the mixture having the most demanding of the characteristics being considered (e.g. the gas classification, the flammable limits, the flash point or ignition temperature) will be present as the largest proportion of the mixture, and the electrical installation should be designed accordingly.

37.2.2 However, this can impose limitations that may be severe, and further consideration of the relative rates and quantities of the materials used in the process and the degree of control thereof may be required. Some relaxation may then be possible, but expert advice should always be sought in these circumstances.

37.2.3 Particular consideration should be given to those materials whose behaviour may be anomalous. It is known, for example, that carbon monoxide, with which Group IIA apparatus may be safely used, may be added in considerable quantity to hydrogen without altering the group of apparatus, namely Group IIC, that has to be used with this latter compound. Carbon monoxide also exhibits unusual behaviour under other test conditions. For example, it has been shown that the addition of moisture to mixtures of carbon monoxide with air to the point of saturation serves to change the gas classification for this material from Group IIA to Group IIB. This change in gas classification is also observed if methane is added to carbon monoxide in the proportion 15 : 85 methane to carbon monoxide.

37.2.4 When the individual components of mixtures and their proportions of the total mixture are precisely known or can be sustained, it is often possible to calculate the resultant flammable limits for the mixture with air. Examples of this care described in Annex E. However, if the mixture is predominantly carbon monoxide, expert advice should be sought.

37.3 Mists

The characteristics described in this standard apply to mixtures of gases and vapours only with air. The distinction to be drawn between a gas and a vapour in this context is simply that the latter may be in contact with its liquid phase at normal temperature and pressure, whereas a gas cannot be liquefied under normal atmospheric conditions. In practice, mists consisting of clouds of condensed vapour can also occur. In general, the characteristics described in this standard should be considered applicable to mists, since local ignition sources or hot surfaces generally may serve to restore the condensed material to its vapour phase.

Section 6 Marking of Apparatus

38 GENERAL

38.1 It has been agreed internationally, that the letters 'Ex' should be used to indicate explosion protection and that this symbol should be accompanied by a lower case better to indicate the type of protection used. The letter code is described in **6**.

38.2 The marking requirements for the various types of explosion protected apparatus shall be in accordance with IS 13346 : 1992.

39 MARKING REQUIREMENTS FOR APPARATUS

39.1 The general marking requirements described in this clause are intended to aid the user in identifying the type of protection and to assist identification of the particular explosion risk for which the apparatus is suitable.

39.2 The marking requirements include the following :

a) Identification of the manufacturer. The manufacturer may be identified by name or trademark.

b) The manufacturer's name or type designation for the apparatus.

c) The certifying authority mark and the certificate number.

d) Identification of the type of protection (*see* **40**).

e) The apparatus sub-group, if applicable. The system of marking for indicating apparatus sub-grouping is described in **40**.

f) The T class or maximum surface temperature. This requirement is described in **8.3**.

g) Any other, relevant information, will normally include voltage and current ratings, under prescribed conditions where necessary, and such other information as may be necessary for the satisfactory operation of the apparatus.

39.3 The marking includes, therefore, not only the manufacturer's name and rating data with which all electrical apparatus should normally be marked, but also sufficient additional information to indicate the suitability of the apparatus for use in particular flammable atmospheres. This is explained in **40** and **41**.

40 EXAMPLES OF MARKING OF APPARATUS

40.1 General

The following examples are included to illustrate the application and interpretation of the marking requirements. They do not represent all the variations of marking that are possible, nor is it intended to include in these examples all the marking requirements that are usually specified. More detailed marking requirements that are relevant to particular types of protection are described in the appropriate standard and in the relevant apparatus standards.

40.2 Flameproof Enclosure 'd'

The marking on apparatus with type of protection 'd' will normally include the following:

a) The symbol for the type of protection 'd';

b) The apparatus group and sub-group; and

c) The temperature classification.

For example, EEx d IIB T5 indicates that the enclosure complies with Group IIB requirements and that the apparatus has a temperature classification of T5.

40.3 Increased Safety Apparatus 'e'

The marking on apparatus with type of protection 'e' will normally include the following to indicate compliance with the requirements of IS 6381 : 1972:

a) The symbol for the type of protection 'e';

b) The apparatus group; and

c) The temperature classification.

For example, EEx e II T3 indicates that the apparatus may be used safely with all flammable gases and vapours allocated to apparatus Group II, subject to a temperature classification of T3.

40.4 Intrinsic Safety 'i'

40.4.1 *Intrinsically Safe Apparatus*

Intrinsically safe apparatus can be category 'ia' or 'ib' and may be suitable for connection to external circuits subject to certain possible limitations on their characteristics.

The marking on apparatus with type of protection 'i' will normally include the following to indicate compliance with the requirements of IS 5780 : 1990:

a) The symbol for the type of protection 'i' and the apparatus category;

b) The apparatus group and sub-group; and

c) The temperature classification.

For example, EEx ia IIC T5 indicates that the apparatus group is IIC and that the apparatus has a temperature classification of T5.

Additionally, there may be marking to indicate the limiting characteristics of external circuits, e.g. $L_{ext} = 12\ \mu H$, $C_{ext} = 1\ 200\ pF$, $U_{max} = 28\ V$.

The second mark indicates the limiting values of inductance, capacitance and voltage of the external circuits which may be connected to the apparatus to maintain its safe use under the conditions indicated by the first mark.

40.4.2 *Associated Electrical Apparatus*

Associated electrical apparatus installed in a non-hazardous area can be category 'ia' or 'ib'. This limitation in its use is denoted on the marking by enclosing the applicable symbols in square brackets.

The marking on such apparatus includes the following:

a) The symbols of the type of protection 'i' and the apparatus category; and

b) The apparatus group and sub-group.

For example, (EEx ib) IIC indicates compliance with IS 5780 : 1980. There is no requirement to mark an apparatus temperature classification since the apparatus is installed in a non-hazardous area.

40.4.3 *Intrinsically Safe Electrical System 'i'*

Certified intrinsically safe electrical systems 'i' which comply with all the requirements for IS 5780 : 1980 will be marked as described in 41.4.1 and additionally will be marked in a strategic position with the letters SYST.

For intrinsically safe electrical systems 'i' complying with the requirements of IS 5780 : 1980 which have not been certified, marking which permits positive identification of the system and reference for the relevant system description will normally be applied.

40.5 Type of Protection 'n'

The marking in accordance with IS 8289 : 1976 on this apparatus will normally include the following to indicate compliance with the requirements of that standard:

a) The symbol of the type of protection 'n' and the apparatus category;

b) The apparatus group; and

c) The temperature classification.

For example, Ex n II T3 indicates that the apparatus may be used safely in Zone 2 areas with all flammable gases and vapours allocated to apparatus Group II, subject to a temperature classification of T3.

40.6 Other Types of Protection

The types of protection that have not been included in the examples in 40.2 to 40.5 will normally be marked in accordance with similar rules.

41 GENERAL NOTES ON MARKING

41.1 General

In 41.2 to 41.4 some of the finer details of marking requirements that have not been indicated in the examples in 40.2 to 40.4 are explained.

41.2 Certificate Number

The certificate number may refer to a single design or to a range of apparatus of similar design. The same number may also be used for modifications to the original design.

Where the certificate number is followed by 'X', it indicates that special conditions for safe use apply, and therefore particular attention should be paid to certification documents before apparatus is selected.

The certificate number may also be followed by 'S'. This suffix indicates that the apparatus so marked is suitable for installation in a safe area only, but that it may form part of a certified system.

41.3 Ex component Approval

Component parts or sub-assemblies forming part of certified apparatus may be the subject of separate component certificates. This procedure is called 'component approval'. Approval Ex components will generally be marked in accordance with the rules described in 38 to 40, with the addition of the letter 'U' after the approval number, but will not normally carry the testing house certification mark.

41.4 Multiple Types of Protection

41.4.1 Increasingly, electrical apparatus for hazardous areas may incorporate more than one type of protection. The examples in 41.4.2 and 41.4.3 serve to illustrate the marking requirements that will normally be applied.

41.4.2 A flameproof apparatus such as a motor may incorporate an increased safety terminal box. In this case, where each type of protection is readily and separately identifiable, each enclosure will normally be marked accordingly.

41.4.3 An apparatus with type of protection 'e' (increased safety) overall may incorporate sparking contacts protected by a flameproof enclosure (type of protection 'd'). In this case, the types of protection that are used internally cannot be identified by external examination other than by inspection of the marking plate. The external marking will indicate the overall protection, which will determine the installation requirements, and may indicate the additional protective features in a secondary manner. For example, an increased safety apparatus with internal flameproof enclosure having a T3 temperature classification would normally be marked as follows:

EEx e d IIC T3.

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
2148 : 1981	Flameproof enclosures for electrical apparatus (*second revision*)
2309 : 1969	Code of practice for the protection of buildings and allied structures against lighting (*first revision*)
3043 : 1987	Code of practice for earthing
5571 : 1979	Guide for selection of electrical equipment for hazardous areas (*first revision*)
5572 (Part 1) : 1978	Classification of hazardous areas (other than mines) for electrical installations: Part 1 Areas having flammable gases and vapours (*first revision*)
5780 : 1980	Specification for intrinsically safe electrical apparatus and circuit (*first revision*)
6381 : 1972	Constructions and testing of electrical apparatus with type of protection 'e'
7689 : 1989	Guide for control of undesirable static electricity (*first revision*)
7820 : 1975	Method of test for ignition temperatures
8062 (Part 1) : 1976	Code of practice for cathodic protection of steel structures: Part 1 General principle
8289 : 1976	Electrical equipment with type of protection 'n'
9570 : 1980	Classification of flammable gases or vapours with air according to their maximum experimental safe gaps and minimum ignition current
9537) (Part 2) : 1981	Conduits for electrical installations: Part 2 Rigid steel conduits
13346 : 1992	General requirements for the electrical apparatus for use in explosive atmospheres

ANNEX B

(*Clause* 1.6, *Note* 2)

RELEVANT INTERNATIONAL, EUROPEAN BRITISH STANDARDS AND INDIAN STANDARDS AND DETAILS OF THE NATIONAL CERTIFYING AUTHORITY AND ITS CERTIFICATION STANDARDS

B-1 EN 50 014 to EN 50 020 and EN 50 039 have been prepared by CENELEC Technical Committee 31. These standards represent technical texts accepted by 17 CENELEC Member National Committees (including the UK), in the three official CENELEC languages, and which carry the strict obligation to be implemented as a national standard, unaltered in presentation or content. This has been done by publishing BS 5501: Parts 1 to 7 and Part 9, which are identical to EN 50 014 to EN 50 020 and EN 50 039, respectively (*see* B-3).

B-2 STANDARDS PRODUCED BY THE INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

As part of a continuing process towards international standardization, many countries including the UK participate in the International Electrotechnical Commission (IEC). This organization produces recommendations which are intended to form the basis for the national standards of each participating country. As specifications for each type of protection and ancillary subjects are developed, these are published in a sequential series of standards each of which is a part of IEC Publication 79 (*see also* B-3). The following parts of Publication 79 have already been published:

79	Electrical apparatus for explosive gas atmospheres
79-0	Part 0 General requirements
79-1	Part 1 Construction and test of flameproof enclosures of electrical apparatus
79-1A	First supplement Appendix D: Method of test for ascertainment of maximum experimental safe gap
79-2	Part 2 Pressurized enclosures
79-3	Part 3 Spark test apparatus for intrinsically-safe circuits
79-4	Part 4 Method of test for ignition temperature
79-4A	First supplement
79-5	Part 5 Sand-filled apparatus
79-6	Part 6 Oil-immersed apparatus
79-7	Part 7 Construction and test of electrical apparatus, type of protection 'e'
79-8	Part 8 Classification of maximum surface temperatures
79-9	Part 9 Marking
79-10	Part 10 Classification of hazardous areas
79-11	Part 11 Construction and test of intrinsically-safe and associated apparatus
79-12	Part 12 Classification of mixtures of gases or vapours with air according to their maximum experimental safe gaps and minimum igniting currents
79-13	Part 13 Construction and use of rooms or buildings protected by pressurization

The following IEC Standards cover related topics:

IEC 34	Rotating electrical machines Part 5 Classification of degrees of protection provided by enclosures for rotating machines
IEC 144 : 1963	Degrees of protection of enclosure for low-voltage switchgear and controlgear (= BS 5420:1977)
IEC 529 : 1976	Classification of degrees of protection provided by enclosures (= BS 5490 : 1977)

B-3 RELEVANT INDIAN STANDARDS

Indian Standards relevant to the use of electrical apparatus in hazardous areas are as follows:

IS 692 : 1973	Paper insulated lead-sheathed cables for electricity supply (*second revision*)
IS 694 : 1977	PVC insulated cables for working voltages up to and including 1 100 volts (*second revision*)
IS 1554 (Part 2) : 1981	For working voltages from 3.3 kV up to and including 11 kV (*first revision*)
IS 2147 : 1962	Degrees of protection provided by enclosures for low-voltage switchgear and controlgear
IS 2148 : 1981	Flameproof enclosures of electrical apparatus (*second revision*)
IS 2206 (Part 1) : 1984	Flameproof electric lighting fittings: Part 1 Well glassed and bulk-hood type
IS 2667 : 1976	Fittings for rigid steel conduits for electrical wiring
IS 2772 : 1982	Non-flameproof mining transformers for use below ground (*first revision*)

IS 4691 : 1985	Degrees of protection provided by enclosures for rotating electrical machinery (*first revision*)
IS 5571 : 1979	Guide for selection of electrical equipment for hazardous areas (*first revision*)
IS 5572 : 1978	Classification of hazardous areas (other than mines) for electrical installation : Part 1 Areas having flammable gases and vapours (*first revision*)
IS 5780 : 1980	Intrinsically safe electrical apparatus and circuits (*first revision*)
IS 6381 : 1972	Construction and testing of electrical apparatus with type of protection 'e'
IS 7389 (Part 1) : 1976	Pressurized enclosures of electrical apparatus for use in explosive atmospheres: Part 1 Pressurized enclosures with no internal source of flammable gas or vapour
IS 7689 : 1974	Guide for control of undesirable static electricity
IS 7693 : 1975	Oil immersed electrical apparatus for use in explosive gas atmospheres
IS 7724 : 1975	Sand-filled protection of electrical equipment for use in explosive atmospheres
IS 7820 : 1975	Method of test for ignition temperatures
IS 8062 (Part 1) : 1976	Code of practice for cathodic protection of steel structures : Part 1 General principles
IS 8224 : 1976	Electric lighting fitting for division 2 areas
IS 8289 : 1976	Electrical equipment with type of protection 'n'
IS 9537 (Part 1) : 1980	General requirements
IS 9537 (Part 2) : 1981	Rigid steel conduits
IS 9628 : 1980	Three-phase induction motors with type of protection 'n'
IS 9968 (Part 1) : 1981	For working voltages up to and including 1 100 volts
IS 12309 : 1989	Code of practice for the protection of buildings and allied structures against lightning (*second revision*)

B-4 NATIONAL APPROVING AUTHORITY FOR ELECTRICAL APPARATUS FOR USE IN HAZARDOUS AREAS

B-4.1 The national approving authorities in India for Electrical Equipment for use in Flammable Atmospheres are as follows:

a) Chief Controllerate of Explosives, Nagpur

b) Directorate General Factory Advice and Labour Institutes, Bombay

B-5 TESTING OF ELECTRICAL APPARATUS FOR USE IN HAZARDOUS AREAS

B-5.1 The testing facilities for checking and testing the electrical apparatus for use in hazardous areas are available with the Central Mining Research Station (CSIR), Barwa Road, Dhanbad (Bihar).

B-6 BIS CERTIFICATION MARKING SCHEME

B-6.1 The certification of electrical apparatus for use in hazardous areas is being done by the Bureau of Indian Standards, New Delhi (BIS) under well defined system of inspection, testing and quality control during preparation. This system, which is devised and supervised by BIS and operated by the producer, has the further safeguard that the apparatus carrying BIS certification mark are continuously checked by BIS for conformity to that Standard.

ANNEX C

(*Clause* 7.1)

FRICTIONAL SPARKING RISKS WITH LIGHT METALS AND THEIR ALLOYS*

C-1 The risk of ignition due to frictional sparking, which though present with ferrous and certain other metals is sufficiently improbable to be discounted, may be sufficiently severe when certain light metals and their alloys are involved that special consideration has to be given to their use, particularly in the more hazardous areas. It is generally recognized that the recommendations in C-2 to C-7 should be noted.

C-2 It has been clearly established that incendive frictional sparking can occur in circumstances where certain light metals or their alloys are brought into suitable contact with other materials, particularly when the other material is an oxygen carrier such as rust. Suitable safeguards have therefore to be taken to prevent the occurrence of such frictional contact in circumstances where a flammable atmosphere may be present, as the simultaneous occurrence of the two sets of circumstances, could lead to ignition.

C-3 As with other ignition risks, the first safeguard is to avoid the occurrence of flammable atmospheres and to site the apparatus whenever practicable in locations where such atmospheres are not likely to occur.

C-4 For rigidly mounted electrical apparatus with light metal enclosures and aluminium armoured or sheathed cable sited in Zone 2 areas, the frictional sparking risk may be disregarded except in those particular circumstances where heavy impact might also initiate the release of flammable material. This applies also in Zone 1 areas, unless the impact risk is high, when the use of light metal enclosures or aluminium protected cables should be avoided unless they are provided with a robust protective covering. Such apparatus and cables should not be used on Zone 0 areas.

C-5 Portable and transportable apparatus with light metal or light alloy enclosures that are otherwise unprotected against frictional contact should not be taken into hazardous areas unless special precautions are taken to ensure safety. Such precautions may include a special permit to work in the assured absence of a flammable atmosphere, though more satisfactory safeguards may be taken by, for example, coating the apparatus with a suitable abrasion resistant material. When such coatings are used they should be subject to regular and careful inspection. The continued use of the apparatus should not be permitted if inspection reveals that the protective material has become damaged to the extent that the underlying protected metal is visible, until such damage has been satisfactorily repaired.

These precautions should be adopted even for apparatus intended for use in Zone 2 areas only, since it may be difficult in practice to prevent the transfer of unprotected portable apparatus to an area of greater risk.

C-6 Provided that the protective cowls for light metal fans on motors are designed so that they are not readily deformed, such fans may be used in Zone 1 and Zone 2 areas since other modes of failure (e.g. bearing failure) are more likely to create a source of ignition. If plastic fans or cowls are used as alternatives, they should be of anti-static material.

C-7 Until further information is available, the use of aluminium conductors in flameproof enclosures should be avoided in those cases where a fault leading to potentially severe arcing involving the conductors may occur in the vicinity of a plain flanged joint. Adequate protection may be afforded by suitable conductor and terminal insulation to prevent the occurrence of faults or by using enclosures with spigot or threaded joints.

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*The term 'light metal' refers to such materials as aluminium, magnesium and titanium which are characterized by their ability when finely divided to react exothermically with atmospheric oxygen and, as a result, to ignite a flammable atmosphere. The term 'light alloy' refers to an alloy containing at least 50% of a light metal by atomic proportions.

ANNEX D

(*Clause* 8.4.3)

DATA FOR FLAMMABLE MATERIALS

D-1 INTRODUCTION

D-1.1 The data for Table 6 has been obtained from a number of references which appear in the bibliography (*see* D-8). Some minor variations in the data appear when references are compared but usually the discrepancy is sufficiently small to be ignored. The values contained in Table 6 are indicative only. For example, naptha and kerosine are general terms not precisely defining the composition of the substance concerned. In addition, impurities can affect various properties. It is recommended therefore that further checks be made on the properties of the particular material involved in the application concerned.

The notes in D-2 to D-9 relate to the description of the data in Table 6.

D-2 CHEMICAL STRUCTURE

D-2.1 The work 'mixture' in col 2 of Table 6 indicates the material is a mixture of materials.

D-3 FLASH POINTS

D-3.1 The value given is the closed cup measurement. When this data is not available the open cup value is given. Open cup values are enclosed in brackets. The symbol < (less than) indicates that the flash point is below the value stated, this value probably being the limit of the apparatus used.

D-4 FLAMMABLE LIMITS

D-4.1 Where flammability data is presented materials with flash points above 40°C, the determinations have been made at an elevated temperature sufficient to give the quoted concentration.

D-5 IGNITION TEMPERATURE AND T CLASS

D-5.1 The preferred data is that recorded in IEC Publication 79-4A (Indian Standard yet to be prepared). In the absence of such data, the values given are the lowest reported from class apparatus tests. When the lowest reported is in other unspecified apparatus, the value is enclosed in brackets. Knowledge of the ignition temperature allows the choice of the apparatus T class suitable for the flammable material to be made. The T class is given in brackets when the lowest reported ignition temperature was determined in unspecified apparatus or apparatus other than glass apparatus.

D-6 GROUP AND SUB-GROUP FOR APPARATUS WITH FLAMEPROOF ENCLOSURE

D-6.1 The groups are the result of maximum experimental safe gap (MESG) determinations, except for values in brackets. These values are estimates based on chemical similarity. There is no lower limit to Group IIC and, therefore, each compound in Group IIC should be considered individually.

D-7 NOTES ON SOME INDIVIDUAL MATERIALS

Acetylene	Type 'd' apparatus for use with acetylene is grouped IIC, but additional requirements for such apparatus for use with this gas are specified in BS 5501: Part 5. (corresponding Indian Standard does not include recommendations for apparatus for acetylene gas).
Carbon disulphide	Group IIC apparatus should only be used with carbon disulphide when the free volume of the enclosure is less than 100 ml. For large volumes, the apparatus should be subjected to special test.
Coke oven gas	This is a mixture of hydrogen, carbon monoxide, and methane. If the sum of the concentrations of hydrogen and carbon monoxide is less than 75%, Group IIB flameproof apparatus is required, otherwise Group IIC. For all concentrations, intrinsically safe apparatus should be Group IIC.
Ethyl nitrate	It is recommended that apparatus of type of protection 'd' is not used in the presence of ethyl nitrate.
Methane	Industrial methane includes methane mixed with not more than 15% by volume of hydrogen.
Xylene	The ignition temperature of o-xylene is 464°C, and of p-xylene is 528°C.

D-8 BIBLIOGRAPHY

Further data on the properties of flammable materials may be found in the following references, some of which were used in the compilation of the tables.

Fire Protection Associated (London). Fire and related properties of industrial chemicals, reprinted 1974.

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Toxic and Hazardous Industrial Chemicals Safety Manual, 1975/76 (Japan).

Coward, H.F. and Jones, G.W. Limits of flammability of gases and vapors. US Bureau of Mines Bulletin 503, 1952.

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Table 6 Data for Flammable Materials for Use with Electrical Equipment

(*Clauses* 8.4.3, 29.1, 29.2, 30.1, 32.2, 33.2, 35.1, 36.3, *Annex* D-1.1 *and* D-2.1)

Name	Formula	Melting Point	Boiling Point	Relative Vapour Density	Flash Point	Flammable Limits				Ignition Temperature	Minimum Igniting Current	T Class of Suitable Apparatus	Apparatus Group
						v/v		m/v					
						LFL	UFL	LFL	UFL				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	C	°C	°C		°C	%	%	mg/l	mg/l	°C	mA		
Acetaldehyde	CH_3CHO	–123	20	1.52	–38	4	57	73	1 040	140	–	T4	IIA
Acetic acid	CH_3COOH	17	118	2.07	40	5.4	16	100	430	485	–	T1	IIA
Acetic anhydride	$(CH_3CO)_2O$	–73	140	3.52	54	2.7	10	–	–	(334)	–	(T2)	IIA
Acetone	$(CH_3)_2CO$	–95	56	2.0	–19	2.15	13	60	310	535	–	(T1)	IIA
Acetonitrile	CH_3CN	–45	82	1.42	5	–	4.4	16	–	523	–	T1	IIA
Acetyl chloride	$CH_3\ COCL$	–112	51	2.7	4	5.0	–	–	–	390	–	T2	(IIA)
Acetylene (*see* D-7)	$CH{\equiv}CH$	–81	–84*	0.9	–	1.5	100	–	–	305	24	T2	IIC
Acrylonitrile	$CH_2{=}CHCN$	–82	77	1.83	–5	3	17	65	380	480	–	T1	IIA
Allyl alcohol	$CH_2{=}CHCH_2OH$	–	–	–	21	–	–	–	–	–	–	–	IIA
Allyl chloride	$CH_2{=}CHCH_2CL$	–135	45	2.64	–20	3.2	11.2	105	360	485	–	T1	IIA
Allylene	$CH_3C{\equiv}CH$	–103	–23	1.38	–	1.7	–	28	–	–	–	–	(IIB)
Ammonia	NH_3	–78	–33	0.59	–	15	28	105	200	630	–	T1	IIA
Amphetamine	$C_6H_5CH_2CH(NH_2)CH_3$	–	200	4.67	<100	–	–	–	–	–	–	–	(IIA)
Aniline	$C_6H_5NH_2$	–6	184	3.22	75	1.2	8.3	–	–	617	–	T1	(IIA)
Benzaldehyde	C_6H_5CHO	–26	179	3.66	65	1.4	–	60	–	190	–	T4	(IIA)
Benzene	C_6H_6	–6	80	2.7	–11	1.2	8	39	270	560	–	T1	IIA
Blue water gas	Mixture	–	–	–	–	–	–	–	–	–	–	T1	(IIC)
1-bromobutane	$CH_3(CH_2)_2CH_2Br$	–112	102	4.72	<21	2.5	–	230	–	265	–	T3	(IIA)
Bromoethane	C_2H_5Br	–119	38	3.75	<–20	6.7	11.3	300	510	510	–	T1	(IIA)
Buta-1,3-diene (Butadiene)	$CH_2{=}CHCH{=}CH_2$	–109	–4	1.87	–	2.1	12.5	25	290	430	65	T2	IIA

*Sublimation temperature.

Table 6 (*Continued*)

Name	Formula	Melting Point	Boiling Point	Relative Vapour Density	Flash Point	Flammable Limits				Ignition Temperature	Minimum Igniting Current	T Class of Suitable Apparatus	Apparatus Group
						v/v		m/v					
						LFL	UFL	LFL	UFL				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	C	°C	°C		°C	%	%	mg/l	mg/l	°C	mA		
Butane	C_4H_{10}	–138	–1	2.05	–60	1.5	8.5	37	210	365	80	T2	IIA
Butanone (Ethyl methyl ketone)	$C_2H_5COCH_3$	–86	80	2.48	–1	1.8	11.5	50	350	505	—	T1	IIA
Butan-1-ol (1-butanol)	$CH_3(CH_2)_2CH_2OH$	–89	118	2.55	29	1.7	9.0	43	350	340	—	T2	IIA
Butyl acetate	$CH_3COOCH_2(CH_2)_2CH_3$	–77	127	4.01	22	1.4	8	58	360	370	—	T2	IIA
Butyl glycolate (butyl hydroxyacetate)	$HOCH_2COOC_4H_9$	—	356	4.45	61	—	—	—	—	—	—	—	(IIB)
Butyle styrene	$C_6H_4C(CH_3)_3 = CH_2$	—	—	—	—	—	—	—	—	—	—	—	IIB
Butylamine	$C_4H_9NH_2$	–104	63	2.52	<–9	—	—	—	—	(312)	—	T2	IIA
Butyldigol	$CH_3(CH_2)_3OCH_2CH_2OCH_2CH_2OH$	88	231	5.59	78	—	—	—	—	225	—	T3	IIA
Butyraldehyde	$CH_3CH_2CH_2CHO$	–97	75	2.48	<–5	1.4	12.5	42	380	230	—	T3	IIA
But-1-ene (1-butene)	$CH_2=CHCH_2CH_3$	–185	–6	1.95	—	1.6	10	35	235	385	—	T2	IIA
But-2-ene (2-butene)	$CH_3CH=CHCH_3$	—	4	1.94	—	1.7	9	—	—	(325)	—	(T2)	IIB
Carbon disulphide (*see* D-7)	CS_2	–112	46	2.64	–20	1.0	60	30	1 900	102	—	T5	IIC
Carbon monoxide (*see* D-7)	CO	–205	–191	0.97	—	12.5	74.2	145	870	605	90	T1	IIB
Chlorobenzene	C_6H_5Cl	45	132	3.88	28	1.3	7.1	60	520	637	—	T1	(IIA)
1-chlorobutane	$CH_3(CH_2)_2CH_2Cl$	–123	78	3.2	<0	1.8	10	65	390	(460)	—	(T1)	IIA
Chloroethane	C_2H_5Cl	–136	12	2.22	—	3.6	15.4	95	400	510	—	T1	(IIA)

Table 6 (*Continued*)

Name (1)	Formula (2)	Melting Point (3)	Boiling Point (4)	Relative Vapour Density (5)	Flash Point (6)	Flammable Limits v/v LFL (7)	Flammable Limits v/v UFL (8)	Flammable Limits m/v LFL (9)	Flammable Limits m/v UFL (10)	Ignition Temperature (11)	Minimum Igniting Current (12)	T Class of Suitable Apparatus (13)	Apparatus Group (14)
	C	°C	°C		°C	%	%	mg/l	mg/l	°C	mA		
2-chloroethanol (Chloroethanol)	CH_2ClCH_2OH	–70	129	2.78	55	5.0	16	160	540	425	–	T2	(IIA)
Chloroethylene (Vinyl chloride)	$CH_2=CHCl$	–154	–14	2.15	–	3.8	29.3	95	770	470	–	T1	IIA
Chloromethane	CH_3Cl	–98	–24	1.78	–	10.7	13.4	150	400	625	–	T1	IIA
Chloromethylmethylether (Chlorodimethyl ether)	CH_3OCH_2Cl	–103	60	–	–	–	–	–	–	–	–	–	(IIA)
1-chloropropane (N-Chloropropane)	C_3H_7Cl	–123	37	2.7	–18	2.8	10.7	70	300	(592)	–	(T1)	(IIA)
2-chloropropane (iso-chloropropane)	$(CH_3)_2CHCL$	–	47	2.7	–32	2.6	11.1	–	–	520	–	T1	IIA
α-Chlorotoluene (Benzyl chloride)	$C_6H_5CH_2Cl$	–39	179	4.36	60	1.2	–	55	–	585	–	T1	(IIA)
1-chloro-2, 3-epoxy propane (Epichlorhydrin)	OCH_2CHCH_2CL	–57	116	3.30	(40)	–	–	–	–	–	–	–	IIA
Coal tar naphtha	Mixture	–	–	–	–	–	–	–	–	272	–	T3	(IIA)
Coke oven gas (*see* D-7)	Mixture	–	–	–	–	–	–	–	–	–	–	–	
Cresol	$CH_3C_6H_4OH$	11	191	3.73	81	1.1	–	45	–	555	–	T1	(IIA)
Crotonaldehyde	$CH_3CH=CHCHO$	–75	102	2.41	13	2.1	15.5	–	–	(230)	–	(T3)	IIB
Cumene	$C_6H_5CH(CH_3)_2$	–97	152	4.13	36	0.88	6.5	–	–	420	–	T2	(IIA)
Cyclobutane	$CH_2(CH_2)_2\,CH_2$	–91	13	1.93	–	1.8	–	42	–	–	–	–	(IIA)
Cycloheptane	$CH_2(CH_2)_5\,CH_2$	–	119	3.39	<–21	–	–	–	–	–	–	–	(IIA)

Table 6 (*Continued*)

Name	Formula	Melting Point	Boiling Point	Relative Vapour Density	Flash Point	Flammable Limits				Ignition Temperature	Minimum Igniting Current	T Class of Suitable Apparatus	Apparatus Group
						v/v		m/v					
						LFL	UFL	LFL	UFL				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	C	°C	°C		°C	%	%	mg/l	mg/l	°C	mA		
Cyclohexane	$CH_2(CH_2)_4\ CH_2$	7	81	2.9	−18	1.2	7.8	40	290	259	—	T3	IIA
Cyclohexanol	$CH_2(CH_2)_4\ CHOH$	24	161	3.45	68	1.2	—	—	—	300	—	T2	(IIA)
Cyclohexanone	$CH_2(CH_2)_4\ CO$	−31	156	3.38	43	1.4	9.4	53	380	419	—	T2	IIA
Cyclohexene	$CH_2(CH_2)_3\ CH{=}CH$	−104	83	2.83	<−20	1.2	—	—	—	(310)	—	(T2)	(IIA)
Cyclohexylamine	$CH_2(CH_2)_4\ CHNH_2$	−118	134	3.42	32	—	—	—	—	290	—	T3	(IIA)
Cyclopentane	$CH_2(CH_2)_3\ CH_2$	−93	47	—	−37	—	—	—	—	(380)	—	(T2)	IIA
Cyclopropane	$CH_2CH_2\ CH_2$	−127	−33	1.45	—	2.4	10.4	40	185	495	—	T1	IIA
Decahydronaphthalene	$CH_2(CH_2)_3\ CHCH(CH_2)_3\ CH_2$	−43	196	4.76	54	0.7	4.9	40	280	260	—	T3	(IIA)
Decane	$C_{10}H_{22}$(Approx)	−30	173	4.9	96	0.8	5.4	—	—	205	—	T3	IIA
Dibutyl ether	$(C_4H_9)_2O$	−95	141	4.48	25	1.5	7.6	48	460	185	—	T4	IIB
Dichlorobenzene	$C_6H_4Cl_2$	−18	179	5.07	66	2.2	9.2	130	750	(640)	—	(T1)	(IIA)
1,1-dichloroethane	CH_3CHCl_2	−98	57	3.42	−10	5.6	16	225	660	440	—	T2	(IIA)
1,2-dichloroethane (ethylene dichloride)	CH_2ClCH_2Cl	−36	84	3.42	(5)	6.2	15.9	—	—	(413)	—	(T2)	IIA
1,1-dichloroethylene (Vinylidene chloride)	$CH_2{=}CCl_2$	—	37	3.4	−18	7.3	16	—	—	(570)	—	(T1)	IIA
1,2-dichloroethylene	$ClCH{=}CHCl$	−122	33	3.55	−10	9.7	12.8	220	650	(440)	—	(T2)	(IIA)
1,2-dichloropropane	$CH_3CHCLCH_2CL$	80	96	3.9	15	3.4	14.5	160	690	555	—	T1	(IIA)
Diethyl ether	$(C_2H_5)_2O$	−116	34	2.55	<−20	1.7	36	50	1 100	170	75	T4	IIB
Diethyl ketone	$C_2H_5COC_2H_5$	—	—	—	(55)	—	—	—	—	—	—	—	IIA

Table 6 (*Continued*)

Name	Formula	Melting Point	Boiling Point	Relative Vapour Density	Flash Point	Flammable Limits v/v LFL	Flammable Limits v/v UFL	Flammable Limits m/v LFL	Flammable Limits m/v UFL	Ignition Temperature	Minimum Igniting Current	T Class of Suitable Apparatus	Apparatus Group
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	C	°C	°C		°C	%	%	mg/l	mg/l	°C	mA		
Diethyl oxalate	$(COOC_2H_5)_2$	–41	180	5.04	76	—	—	—	—	—	—	—	IIA
Diethyl sulphate	$(C_2H_5)_2SO_4$	–25	208	5.31	104	—	—	—	—	—	—	—	IIA
Diethylamine	$(C_2H_5)_2NH$	–50	56	2.53	<–20	1.7	10.1	50	305	310	—	(T2)	(IIA)
2-diethylaminoethanol	$(C_2H_5)_2NC_2H_4OH$	—	161	4.04	(60)	—	—	—	—	—	—	—	(IIA)
Diethyldichlorosilane	$(C_2H_5)_2SiCl_2$	—	—	—	—	—	—	—	—	—	—	—	IIC
Dihexyl ether	$(CH_3(CH_2)_5)_2O$	–43	227	6.43	75	—	—	—	—	185	—	T4	(IIA)
Di-isobutylene	$C_2H_5CH(CH_3)CH(CH_3)C_2H_5$	–106	105	3.87	(2)	—	—	—	—	(305)	—	(T2)	(IIA)
Di-isopropyl ether	$((CH_3)_2CH)_2O$	–86	69	3.52	–28	1.4	21	—	—	(416)	—	(T2)	IIA
Dimethyl ether	$(CH_3)_2O$	–141	–25	1.59	—	3.7	27.0	38	520	—	—	—	IIB
Dimethylamine	$(CH_3)_2NH$	–92	7	1.55	—	2.8	14.4	52	270	(400)	—	(T2)	IIA
Dimethylaniline	$C_6H_5(CH_3)_2NH_2$	2	194	4.17	63	1.2	7.0	60	350	370	—	T2	(IIA)
Dimethylformamide (Formdimethylamide)	$HCON(CH_3)_2$	–61	152	2.51	58	2.2	15.2	—	—	(440)	—	(T2)	IIA
1,4-dioxane	$\underline{OCH_2CH_2OCH_2\ CH_2}$	10	101	3.03	11	1.9	22.5	70	820	379	—	T2	IIB
1,3-dioxolane	$\underline{OCH_2CH_2\ OCH_2}$	–26	74	2.55	(2)	—	—	—	—	—	—	—	(IIB)
Dipentyl ether (di-n-amylether) (Diamethyl ether)	$(C_5H_{11})_2O$	–69	170	5.45	(57)	—	—	—	—	170	—	T4	(IIA)
Dipropyl ether	$(C_3H_7)_2O$	–122	90	3.53	<21	—	—	—	—	170	—	T4	(IIB)
Ditertiary butyl peroxide	$(CH_3)_3COOC(CH_3)_3$	—	—	—	18	—	—	—	—	170	—	T4	IIB
1,2-epoxypropane (Propylene oxide)	$CH_3\underline{CHCH_2O}$	—	—	—	–37	—	—	—	—	—	—	—	IIB

Table 6 (*Continued*)

Name	Formula	Melting Point	Boiling Point	Relative Vapour Density	Flash Point	Flammable Limits				Ignition Temperature	Minimum Igniting Current	T Class of Suitable Apparatus	Apparatus Group
						v/v		m/v					
						LFL	UFL	LFL	UFL				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	C	°C	°C		°C	%	%	mg/l	mg/l	°C	mA		
Ethane	CH_3CH_3	–183	–87	1.04	—	3.0	15.5	37	195	515	70	T1	IIA
Ethanethiol (Ethyl mercaptan)	C_2H_5SH	–148	35	2.11	–20	2.8	18	70	460	295	—	T3	IIA
Ethanol	C_2H_5OH	–144	78	1.59	12	3.3	19	67	290	425	75	T2	IIA
Ethanolamine	$NH_2CH_2CH_2OH$	10	172	2.1	85	—	—	—	—	—	—	—	(IIA)
2-ethoxyethanol	$C_2H_5OCH_2CH_2OH$	—	135	3.1	95	1.8	15.7	—	—	235	—	T3	IIB
Ethoxyethyl acetate	$CH_3COOCH_2CH_2OC_2H_5$	—	156	4.6	47	—	—	—	—	380	—	T2	IIA
Ethyl acetate	$CH_3COOCH_2CH_3$	83	77	3.04	–4	2.1	11.5	75	420	460	—	T1	IIA
Ethyl acetoacetate	$CH_3COCH_2COOC_2H_5$	—	180	—	(84)	—	—	—	—	295	—	T3	IIB
Ethyl acetylene	$C_2H_5C{\equiv}CH$	—	—	—	—	—	—	—	—	—	—	—	IIB
Ethyl acrylate	$CH_2=CHCOOC_2H_5$	<–75	100	3.45	9	1.8	—	74	—	—	—	—	IIB
Ethyl benzene	$C_2H_5C_6H_5$	–95	135	3.66	15	1.0	6.7	44	—	431	—	T2	(IIA)
Ethyl cyclobutane	$C_2H_5\underline{CHCH_2CH_2\ CH_2}$	—	—	2.0	<–16	1.2	7.7	—	—	210	—	T3	(IIA)
Ethyl cyclohexane	$C_2H_5\ \underline{CH(CH_2)_4\ CH_2}$	—	131	3.87	14	0.9	6.6	—	—	262	—	T3	(IIA)
Ethyl cyclopentane	$C_2H_5\ \underline{CH(CH_2)_3\ CH_2}$	—	103	3.4	1	1.1	6.7	—	—	260	—	T3	IIA
Ethyl formate	$HCOOCH_2CH_3$	–80	54	2.55	<–20	2.7	16.5	80	500	440	—	T2	(IIA)
Ethyl methacrylate	$CH_2=CCH_3COOC_2H_5$	—	240	3.9	(20)	—	—	—	—	—	—	—	IIA
Ethyl methyl ether	$CH_3OC_2H_5$	—	8	2.087	—	2.0	10.1	49	255	190	—	T4	(IIB)
Ethyl nitrate (*see* D.7)	$CH_3CH_2ONO_2$	–112	89	3.14	10	4.0	—	—	—	—	—	—	—
Ethyldigol	$CH_3CH_2OCH_2CH_2OCH_2CH_2OH$	—	202	4.62	94	—	—	—	—	—	—	—	IIA

Table 6 (*Continued*)

Name	Formula	Melting Point	Boiling Point	Relative Vapour Density	Flash Point	Flammable Limits v/v LFL	Flammable Limits v/v UFL	Flammable Limits m/v LFL	Flammable Limits m/v UFL	Ignition Temperature	Minimum Igniting Current	T Class of Suitable Apparatus	Apparatus Group
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	C	°C	°C		°C	%	%	mg/l	mg/l	°C	mA		
Ethylene	$CH_2{=}CH_2$	−169	−104	0.97	—	2.7	34	31	390	425	45	T2	IIB
Ethylene diamine (Diaminoethane)	$NH_2CH_2CH_2NH_2$	8	116	2.07	34	—	—	—	—	385	—	T2	IIA
Ethylene oxide	$\underbrace{CH_2CH_2O}$	−112	11	1.52	—	3.7	100	55	1 820	440	40	T2	IIB
Formaldehyde	HCHO	−117	−19	1.03	—	7	73	87	10	424	—	T2	IIB
Formic acid	HCOOH	—	101	1.6	68	—	—	—	—	(520)	—	(T1)	IIA
2-furaldehyde (Furfuraldehyde)	$\underbrace{OCH{=}CHCH{=}C}CHO$	—	161	3.3	60	2.1	19.3	—	—	315	—	T2	IIA
Furan	$\underbrace{CH{=}CHCH{-}CHO}$	—	—	—	60	—	—	—	—	—	—	—	IIA
Heptane	C_7H_{16}	−91	98	3.46	−4	1.1	6.7	46	280	215	75	T3	IIA
Heptan-1-ol (1-Heptanol)	$C_7H_{15}OH$	−34	176	4.03	60	—	—	—	—	—	—	—	IIA
Heptan-2-one (Amyl methyl ketone)	$CH_3CO(CH_2)_4CH_3$	−35	151	3.94	(49)	—	—	—	—	—	—	—	(IIA)
Hept-2-one (2-Heptene)	$CH_3(CH_2)_3CH{=}CHCH_3$	—	—	—	<0	—	—	—	—	—	—	—	IIA
Hexane	$CH_3(CH_2)_4CH_3$	−95	69	2.97	−21	1.2	7.4	42	265	233	75	T3	IIA
Hexan-2-one (Butyl methyl ketone)	$CH_3CO(CH_2)_3CH_3$	−56	28	3.46	23	1.2	8	50	330	(530)	—	(T1)	(IIA)
Hydrogen cyanide	HCN	—	26	0.90	−18	5.6	40	—	—	(538)	—	(T1)	IIB
Hydrogen sulphide	H_2S	−86	−60	1.19	—	4.3	45.5	60	650	270	—	T3	(IIB)
Hydrogen (*see* D.7)	H_2	−259	−253	0.07	—	4.0	75.6	3.3	64	560	21	T1	IIC

Table 6 (*Continued*)

Name	Formula	Melting Point	Boiling Point	Relative Vapour Density	Flash Point	Flammable Limits				Ignition Temperature	Minimum Igniting Current	T Class of Suitable Apparatus	Apparatus Group
						v/v		m/v					
						LFL	UFL	LFL	UFL				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	C	°C	°C		°C	%	%	mg/l	mg/l	°C	mA		
4-hydroxy-4-methylpenthan-2-one (Diacetyl alcohol)	$CH_3COCH_2C(CH_3)_2OH$	–47	166	4.0	58	1.8	6.9	—	—	680	—	T1	(IIA)
Isopentane	$(CH_3)_2CHCH_2CH_3$	—	—	—	<–51	—	—	—	—	—	—	—	IIA
Isopropyl nitrate	$(CH_3)_2CHONO_2$	—	105	—	20	2	100	—	—	175	—	T4	(IIB)
ISO-octane	$(CH_3)_2CHCH_2C(CH_3)_3$	—	—	—	–21	—	—	—	—	411	—	T2	IIA
Kerosine	Mixture	—	150	—	38	0.7	5	—	—	210	—	T3	(IIA)
(RS)-p-mentha-1, 8-diene (Dipentene)	$C_{10}H_{16}$	–75	175	4.66	42	0.7	6.1	—	—	237	—	—	IIA
Metaldehyde	$(C_2H_4O)_4$	246*	112+	6.07	36	—	—	—	—	—	—	—	(IIA)
Methane (firedamp)	CH_4	–182	–161	0.55	—	5	15	—	—	595	85	T1	I
Methane (industrial) (*see* D-7)	CH_4	—	—	—	—	—	—	—	—	—	—	T1	IIA
Methanol	CH_3OH	–98	65	1.11	11	6.7	36	73	350	455	70	T1	IIA
2-methoxyethanol	$CH_3OCH_2CH_2OH$	–86	124	2.63	39	2.5	14	80	630	285	—	T3	IIB
Methyl acetate	CH_3COOCH_3	–99	57	2.56	–10	3.1	16	95	500	475	—	T1	IIA
Methyl acetoacetate	$CH_3CO_2CH_2COCH_3$	—	170	4.0	67	—	—	—	—	280	—	T3	(IIA)
Methyl acetylene	$CH_3C{\equiv}CH$	—	–23	1.4	—	1.7	—	—	—	—	—	—	IIB
Methyl acrylate	$CH_2{=}CHCOOCH_3$	<–75	80	3.0	–3	2.8	25	100	895	—	—	—	IIB
Methyl cyclobutane	$CH_3\underbrace{CHCH_2CH_2CH_2}$	—	—	—	—	—	—	—	—	—	—	—	(IIA)
Methyl cyclohexane	$CH_3\underbrace{CH(CH_2)_4CH_2}$	–127	101	3.38	–4	1.15	6.7	45	—	260	—	T3	(IIA)

*In an enclosed vessel

+Sublimation temperature

Table 6 (*Continued*)

Name	Formula	Melting Point	Boiling Point	Relative Vapour Density	Flash Point	Flammable Limits v/v LFL	Flammable Limits v/v UFL	Flammable Limits m/v LFL	Flammable Limits m/v UFL	Ignition Temperature	Minimum Igniting Current	T Class of Suitable Apparatus	Apparatus Group
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	C	°C	°C		°C	%	%	mg/l	mg/l	°C	mA		
Methyl cyclohexanol	$C_7H_{13}OH$ (isomer not stated)	−38	168	3.95	68	—	—	—	—	295	—	T3	(IIA)
Methyl cyclopentane	$CH_3\ CH(CH_2)_3\ CH_2$	—	72	2.9	—	—	—	—	—	—	—	—	(IIA)
Methyl formate	$HCOOCH_3$	−100	32	2.07	<−20	5	23	120	570	450	—	T1	IIA
Methyl methacrylate	$CH_2{=}CCH_3COOCH_3$	—	—	—	(10)	—	—	—	—	—	—	—	IIA
2-methyl propan-1-ol [Butanol (ISO)]	$(CH_3)_2CHCH_2OH$	−108	107	2.55	—	1.7	10.9	—	—	408	—	(T2)	IIA
Methyl styrene	C_9H_{10} (isomer not stated)	—	172	4.1	57	0.7	—	—	—	(495)	—	(T1)	(IIA)
Methylamine	CH_3NH_2	−92	−6	1.07	—	5	20.7	60	270	430	—	T2	IIA
4-methylpentan-2-one (Iso-butyl methyl ketone)	$(CH_3)_2CHCH_2COCH_3$	−80	116	3.45	16	1.4	7.5	—	—	(459)	—	(T1)	IIA
Morpholine	$OCH_2CH_2NHCH_2\ CH_2$	−3	128	3.0	(40)	—	—	—	—	(310)	—	(T2)	IIA
Naphtha	Mixture	—	35	2.5	−6	0.9	6	—	—	290	—	T3	(IIA)
Naphthalene	$C_{10}H_8$	80	218	4.42	77	0.9	5.9	45	320	528	—	T1	(IIA)
Nitrobenzene	$C_6H_5NO_2$	6	211	4.25	88	1.8	—	90	—	480	—	T1	IIA
Nitroethane	$C_2H_5NO_2$	−90	115	2.58	27	—	—	—	—	410	—	T2	IIB
Nitromethane	CH_3NO_2	−29	101	2.11	36	—	—	—	—	415	—	T2	IIA
1-nitropropane	$C_3H_7NO_2$	−108	131	3.06	49	—	—	—	—	420	—	T2	IIB
Nonane	C_9H_{20}	−54	151	4.43	30	0.8	5.6	37	300	205	—	T3	(IIA)
Nonanol	$C_9H_{19}OH$	—	178	4.97	75	0.8	6.1	—	—	—	—	—	(IIA)
n-Hexanol	$C_6H_{13}OH$	−45	157	3.5	63	1.2	—	—	—	—	—	—	IIA
Octaldehyde	$C_7H_{15}CHO$	—	163	4.42	52	—	—	—	—	—	—	—	(IIA)

Table 6 (*Continued*)

Name	Formula	Melting Point	Boiling Point	Relative Vapour Density	Flash Point	Flammable Limits				Ignition Temperature	Minimum Igniting Current	T Class of Suitable Apparatus	Apparatus Group
						v/v		m/v					
						LFL	UFL	LFL	UFL				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	C	°C	°C		°C	%	%	mg/l	mg/l	°C	mA		
Octane	$CH_3(CH_2)_6CH_3$	–56	126	3.93	13	1.0	3.2	—	—	210	—	T3	IIA
Octanol	$C_8H_{17}OH$	–16	195	4.5	81	—	—	—	—	—	—	—	IIA
Paraformaldehyde	poly (CH_2O)	—	25	—	70	—	—	—	—	300	—	T2	IIB
Paraldehyde	$(CH_3CHO)_3$	12	124	4.56	17	1.3	—	70	—	235	—	T3	(IIA)
Pentane (mixed isomers)	C_5H_{12}	130	36	2.48	<–20	1.4	8.0	41	240	285	73	T3	IIA
Pentane-2, 4-dione (Acetyl acetone)	$CH_3COCH_2COCH_3$	–23	140	3.5	34	1.7	—	—	—	340	—	T2	IIA
Pentanol (mixed isomers)	$C_5H_{11}OH$	–78	138	3.04	34	1.2	10.5	44	380	300	—	T2	IIA
Pentylacetate (Amyl acetate)	$CH_3COOC_5H_{11}$	–78	147	4.48	25	1.0	7.1	60	550	375	—	T2	IIA
Petroleum	Mixture	—	—	—	<–20	—	—	—	—	—	—	—	(IIA)
Phenol	C_6H_5OH	41	182	3.24	75	—	—	—	—	605	—	T1	(IIA)
Propane	$CH_3CH_2CH_3$	–188	–42	1.56	—	2.0	9.5	39	180	470	70	T1	IIA
Propanethiol (Propyl mercaptan)	C_3H_7SH	—	—	—	—	—	—	—	—	—	—	—	(IIB)
Propan-1-ol	$CH_3CH_2CH_2OH$	–126	97	2.07	15	2.15	13.5	50	340	405	—	T2	IIB
Propan-2-ol	$(CH_3)_2CHOH$	–86	83	2.07	12	2.0	12	—	—	425	—	T2	IIA
Propene (Propylene)	$CH_2{=}CHCH_3$	–185	–48	1.5	—	2.0	11.7	35	210	(455)	—	(T1)	IIA
Propyl acetate	$CH_3COOCH_2CH_2CH_3$	—	—	—	14	—	—	—	—	—	—	—	IIA
Propylamine	$CH_3(CH_2)_2NH_2$	–101	32	2.04	<–20	2.0	10.4	49	260	(320)	—	(T2)	IIA
Pyridine	Mixture	–42	115	2.73	17	1.8	12.0	56	350	550	—	T1	(IIA)

Table 6 (*Concluded*)

Name	Formula	Melting Point	Boiling Point	Relative Vapour Density	Flash Point	Flammable Limits v/v LFL	Flammable Limits v/v UFL	Flammable Limits m/v LFL	Flammable Limits m/v UFL	Ignition Temperature	Minimum Igniting Current	T Class of Suitable Apparatus	Apparatus Group
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	C	°C	°C		°C	%	%	mg/l	mg/l	°C	mA		
P-cymene	$CH_3C_6H_4CH(CH_3)_2$	–70	177	4.62	47	0.7	5.6	–	–	435	–	T2	(IIA)
Styrene	$C_6H_5CH{=}CH_2$	–31	145	3.6	30	1.1	8.0	45	350	490	–	T1	(IIA)
Tetrafluoroethylene	$CF_2{=}CF_2$	–	–	–	–	–	–	–	–	–	–	–	IIB
Tetrahydrofuran	$CH_2(CH_2)_2CH_2O$	–108	64	2.49	–17	2.0	11.8	46	360	224	–	T3	IIB
Tetrahydrofurfuryl alcohol	$OCH_2CH_2CH_2\ CHCH_2OH$	–	178	3.52	70	1.5	9.7	60	410	280	–	T3	IIB
Tetrahydrothiophen	$CH_2(CH_2)_2CH_2S$	–	–	–	–	–	–	–	–	–	–	–	IIA
3a,4,7,7a-tetrahydro-4, 7-methanoindene (Dicyclopentadiene)	$CHCH{=}CHCH_2CHCHCH{=}CHCHCH_2$	–	–	–	(32)	–	–	–	–	–	–	–	IIA
Thiophen	$CH{=}CHCH{=}CHS$	–	84	2.90	–1	–	–	–	–	–	–	–	IIA
Toluene	$C_6H_5CH_3$	–95	111	3.18	6	1.2	7	46	270	535	–	T1	(IIA)
Toluidine	$CH_3C_6H_4NH_2$	–16	200	3.7	85	–	–	–	–	480	–	T1	(IIA)
Triethylamine	$(C_2H_5)_3N$	–115	89	3.5	0	1.2	8	50	340	–	–	–	(IIA)
α,α,α-trifluorotoluene (Benzotrifluoride)	$C_6H_5CF_3$	–	102	5.0	12	–	–	–	–	–	–	–	IIA
Trimethylamine	$(CH_3)_3N$	–117	3	2.04	–	2.0	11.6	49	285	(190)	–	(T4)	IIA
Trimethylbenzene	$C_6H_3(CH_3)_3$	–45	165	4.15	–	–	–	–	–	470	–	T1	(IIA)
1,3,5-trioxane	$OCH_2OCH_2O\ CH_2$	62	115	3.11	(45)	3.6	29	135	1 110	410	–	T2	IIB
Turpentine	Mixture	–	149	–	35	0.8	–	–	–	254	–	T3	(IIA)
Vinyl acetate	$CH_3COOCH{=}CH_2$	–	–	–	–7	–	–	–	–	–	–	–	IIA
Vinyl chloride	$CH_2{=}CHCl$	–	–	–	–	–	–	–	–	–	–	–	IIA
Xylene (*see* D-7)	$C_6H_4(CH_3)_2$	–25	144	3.66	30	1.0	6.7	44	335	464	–	T1	IIA

ANNEX E

(*Clause* 37.2.4)

CALCULATION OF THE FLAMMABLE LIMITS FOR A MIXTURE OF GASES

NOTE — This annexure may be helpful for use with IS 5572 (Part 1) : 1978.

E-1 LIMITS FOR SAMPLE MIXTURES

E-1.1 General

Frequently, explosion risks arise from mixtures of flammable materials with air. Though only the most general of rules can be indicated for ensuring the safe use of electrical apparatus with mixtures of gases, it is often desirable to be able to establish with some degree of confidence the flammable limits for such mixtures in order that local explosion risk can be avoided. A method that may be used to calculate the flammable limits of most mixtures of flammable gases is described in E-1.2. Though this method achieves a satisfactory degree of accuracy for most applications, it is always advisable to apply caution where the expected total concentration of combustible is near to the calculated value for the appropriate flammable limit. Particular care should also be taken in circumstances where catalytic effects between individual components of a mixture are suspected. General purpose calculations cannot take such effects into account.

E-1.2 Method of Calculation

The method of calculation is based on a simple relationship due to Le Chatelier connecting the lower flammable limits for any two gases in air with the lower limit for any mixture of them. The relationship is expressed by the following equation:

$$\frac{n_1}{N_1} + \frac{n_2}{N_2} = 1$$

where

N_1 and N_2 are the lower flammable limits in air for each combustible gas separately (in %); and

n_1 and n_2 are the percentages of each gas present in any mixture of them that is itself a lower limit mixture.

The formula indicates, for example, that a mixture of air, carbon monoxide and hydrogen that contains one-quarter of the amount of carbon monoxide and three-quarters of the amount of hydrogen necessary to form lower limit mixtures with air independently (i.e. one-quarter of 14% approximately and three-quarters of 4% respectively) will itself be a lower limit mixture.

The formula may be generalized to apply to any number of gases. Thus:

$$\frac{n_1}{N_1} + \frac{n_2}{N_2} + \frac{n_3}{N_3} + \quad = 1$$

The formula may be applied also to upper limit mixtures with suitable redefinition of the terms n_1, etc, and N_1, etc.

The equation may be rendered more useful as follows. (It is assumed that the terms used are consistent, i.e. they are all lower limit mixtures or they are all upper limit mixtures).

Let P_1, P_2, P_3, etc, represent the proportions of each combustible gas present, ignoring air and inert gases, so that:

$$P_1 + P_2 + P_3 + \ldots\ldots = 100$$

and let L represent the flammable limit (upper or lower, as appropriate) so that:

$$L = n_1 + n_2 + n_3 + \ldots$$

since $n_1/L = Pl/100$, then substituting in equation (2)

$$L/100\,(P_1/N_1 + P_2/N_2 + P_3/N_3 \ldots) = 1$$

and therefore

$$L = \frac{100}{\frac{P_1}{N_1} + \frac{P_2}{N_2} + \frac{P_3}{N_3} + \ldots\ldots}$$

E-1.3 Example

As an example of the use of this equation, consider the determination of the lower limit for a gas mixture representative of natural gas.

The natural gas might comprise

methane in the proportion of 80% (P_1) (lower limit 5.32%)

ethane in the proportion of 15% (P_2) (lower limit 3.22%)

propane in the proportion of 4% (P_3) (lower limit 2.37%)

butane in the proportion of 1% (P_4) (lower limit 1.85%)

The lower flammable limit of this mixture with air would be:

$$L = \frac{100}{\frac{80}{5.32} + \frac{15}{3.22} + \frac{4}{2.37} + \frac{1}{1.85}} = 4.55\%$$

E-2 LIMITS FOR COMPLEX INDUSTRIAL GAS MIXTURES

E-2.1 Method of Calculation

A flammable gas mixture encountered in many industrial processes comprises hydrogen, carbon monoxide, methane, nitrogen, carbon dioxide and oxygen. The procedure to be used for calculating the flammable limits for mixture of these gases is as follows:

a) The composition of the mixture is first recalculated on an air-free basis. The amount of each gas is expressed therefore as a percentage of the total air-free mixture.

b) A somewhat arbitrary dissection of the air-free mixture developed from step (a) is made into simpler mixtures, each of which contains only one flammable gas and part or all of the nitrogen and carbon dioxide.

c) The appropriate limits for each of the mixtures obtained from step (b) are obtained from available data (*see* Fig. 1 and 2, which give available data for the flammable limits of hydrogen, carbon monoxide, methane, ethane and benzene with various amounts of carbon dioxide and nitrogen as inert diluent components).

d) The limits of the air-free mixture are than calculated from the data for the dissected mixtures obtained in step (c) using equation (6), were P_1, P_2, P_3, etc, are the proportions of the dissected mixtures, in percentages, and N_1, N_2, N_3 etc, are their respective limits.

e) From the limits of the air-free complex mixture thus obtained, the limits of the original complex mixture which included air can be deduced.

E-2.2 Example

The following is an example of the step-by step calculation outlined in E-2.1.

a) The constituent components of the gas mixture are indicated in Table 7. The composition of the air-free mixture, indicated in the third col of the table, may be calculated as follows:

   The amount of air in the mixture is 2.8 × 100/20.9 or 13.4%. The air-free mixture is therefore 86.6% of the whole. When the original proportions of carbon dioxide, carbon monoxide, methane and hydrogen are divided by 86.6 and multiplied by 100, the air-free percentages are obtained. The nitrogen percentage is the difference between 100 and the sum of these percentages.

Table 7 Components of the Industrial Gas Mixture

Constituent Components of Industrial Gas Mixture	Composition %	Composition Calculated on Air-Free Basis %
Carbon dioxide	13.8	15.9
Oxygen	2.8	0.0
Carbon monoxide	4.3	5.0
Methane	3.3	3.8
Hydrogen	4.9	5.7
Nitrogen	70.9	69.6

b) The flammable gases are paired with the inert gases to form separate mixtures, as shown in Table 8.

c) The flammable limits for the separate or dissected mixtures, taken from Fig. 1, are indicated in col 7 and 8 of Table 8.

d) The values for the flammable limits of these simpler mixtures and for the percentages of the air-free mixture that each of these simpler

Table 8 Flammability Limits of Simpler Mixtures

[*Clause* E-2.2 (b)]

Flammable Material	Amount of Flammable Material	Carbon Dioxide	Nitrogen	Total	Ratio of Inert to Combustible Gas	Flammable Limits from Fig. 1	
						Lower	Higher
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	%	%	%	%		%	%
Carbon monoxide	5.0	–	17.5	22.5	3.5	61.0	73.0
Methane	3.8	–	20.9	24.7	5.5	36.0	41.5
Hydrogen	5.7 { 3.0 2.7	– 15.9	31.2 –	34.2 18.6	10.4 5.9	50.0 32.0	76.0 64.0
Total	14.5	15.9	69.6	100.0	–	–	–

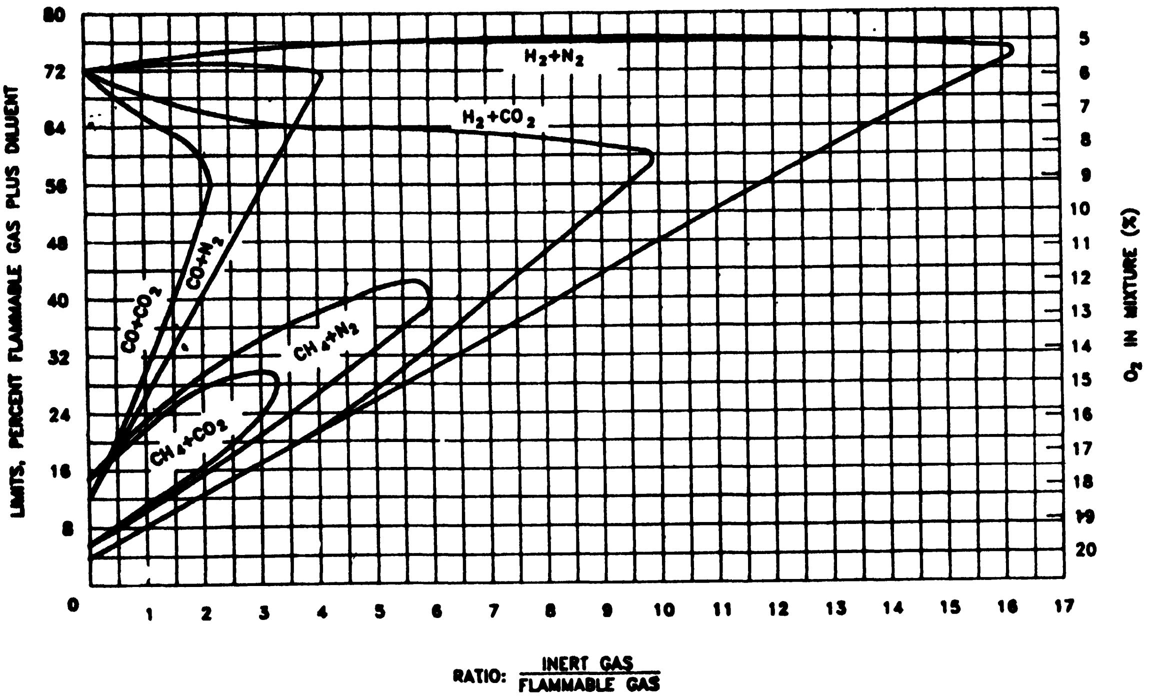

FIG. 1 LIMITS OF FLAMMABILITY OF HYDROGEN, CARBON MONOXIDE, AND METHANE CONTAINING VARIOUS AMOUNTS OF CARBON DIOXIDE AND NITROGEN

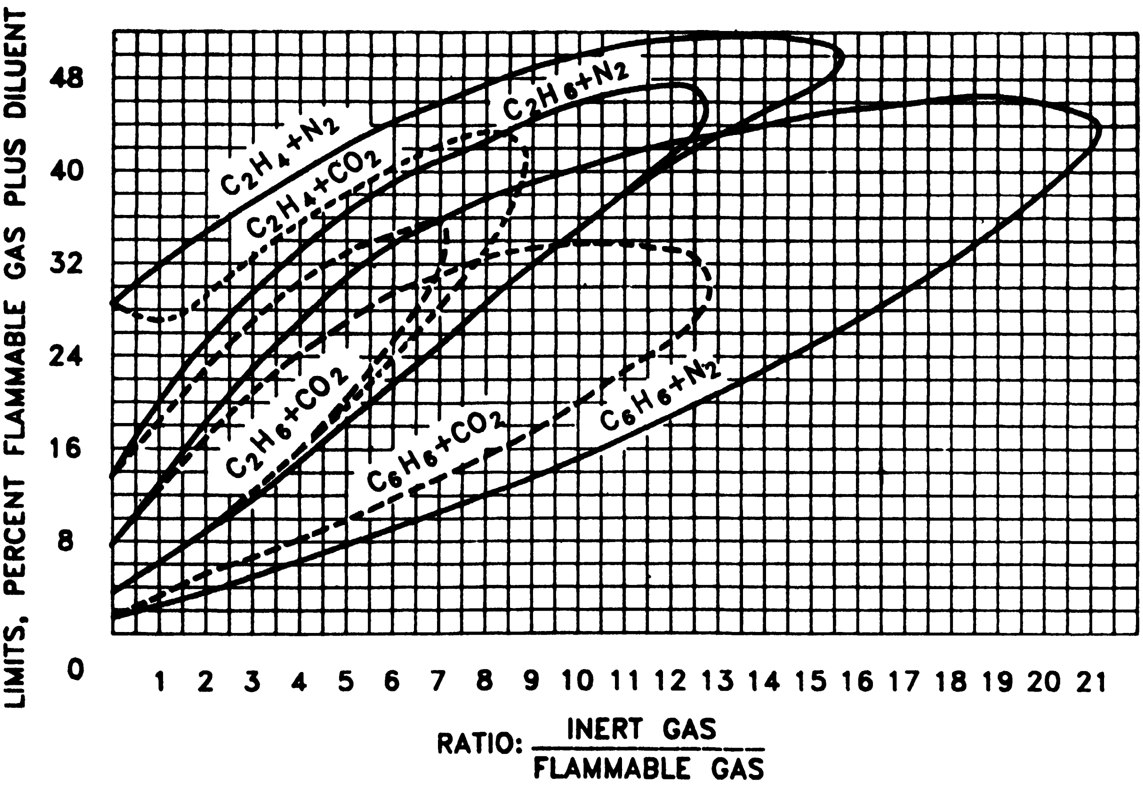

FIG. 2 LIMITS OF FLAMMABILITY OF ETHANE, ETHYLENE AND BENZENE CONTAINING VARIOUS AMOUNTS OF CARBON DIOXIDE AND NITROGEN

mixtures represents (*see* col 5 of Table 8) permit calculation of the flammable limits for the complex air-free mixture. Thus, the lower flammable limit (LF) (in %) is given by the following equation:

$$\text{LFL} = \frac{100}{\frac{22.5}{61} + \frac{24.7}{36} + \frac{34.2}{50} + \frac{18.6}{32}} = 43\%$$

The upper flammable limit (UFL) (in %) is given by the following equation:

$$\text{UFL} = \frac{100}{\frac{22.5}{73} + \frac{24.7}{41.5} + \frac{34.2}{76} + \frac{18.6}{64}} = 61\%$$

e) As the air-free mixture is 86.6% of the complete sample mixture, the flammable limits in air for the sample mixture are 43 × 100/86.6 and 61 × 100/86.6, or 50% and 70% respectively. Thus, the original sample will be flammable within the limits of 50% and 70% in air.

E-2.3 Further Information

Further notes of the limitations of these calculations and the precautions that should be taken with such calculations are available (*see* Coward, H.F. and Jones, G.W. Limits of flammability of gases and vapors. US Bureau of Mines Bulletin 503, 1952).

(*Continued from second cover*)

PAGE

TABLE 1 TYPES OF PROTECTION 3
TABLE 2A SELECTION OF APPARATUS, ACCORDING TO ZONE OF RISK ... 4
TABLE 2B MINIMUM ACTIONS ON FAILURE OF PROTECTIVE GAS FOR TYPE OF PROTECTION 'p'
TABLE 3 RELATIONSHIP BETWEEN T CLASS AND MAXIMUM SURFACE TEMPERATURE 5
TABLE 4 EXAMPLE OF SCHEDULE FOR INITIAL INSPECTION 11
TABLE 5 EXAMPLE OF SCHEDULE FOR SUBSEQUENT INSPECTIONS 11
TABLE 6 DATA FOR FLAMMABLE MATERIALS FOR USE WITH ELECTRICAL EQUIPMENT 24
TABLE 7 COMPONENTS OF THE INDUSTRIAL GAS MIXTURE 36
TABLE 8 FLAMMABILITY LIMITS OF SIMPLER MIXTURES 36

FIGURE 1 LIMITS OF FLAMMABILITY OF HYDROGEN, CARBON MONOXIDE AND METHANE CONTAINING VARIOUS AMOUNTS OF CARBON DIOXIDE AND NITROGEN ... 37
FIGURE 2 LIMITS OF FLAMMABILITY OF ETHANE, ETHYLENE AND BENZENE CONTAINING VARIOUS AMOUNTS OF CARBON DIOXIDE AND NITROGEN ... 37

FOREWORD

This Indian Standard (Part 1) was adopted by the Bureau of Indian Standards, after the draft finalized by the Electrical Apparatus for Explosive Atmospheres Sectional Committee had been approved by the Electrotechnical Division Council.

Many industrial processes involve the generation, processing, handling and storage of flammable and potentially explosive gases, vapours and mists. Where such materials may be present appropriate precautions have to be taken to design or locate electrical apparatus so that electrical arcs, sparks, hot surfaces or frictional sparks produced by such apparatus do not cause ignition.

Several techniques are available for the protection of electrical apparatus situated in hazardous areas. These techniques are described in this code which takes into account the developments that have taken place in area classification and the design, manufacture and use of electrical apparatus for hazardous areas.

The following standards on the selection, installation and maintenance recommendations appropriate to the types of protection that may be used to achieve safe operation of equipment in potentially explosive atmospheres shall be prepared in due course. This would provide basic recommendations applicable to all other stanards:

a) Installation and maintenance requirements for electrical apparatus with type of protection 'd' Flameproof enclosure.
b) Installation and maintenance requirements for electrical apparatus with type of protection 'i' Intrinsically safe electrical apparatus and systems.
c) Installation and maintenance requirements for electrical apparatus protected by pressurization 'p' and by continuous dilution, and for pressurized rooms.
d) Installation and maintenance requirements for electrical apparatus with type of protection 'e'. Increased safety.
e) Installation and maintenance requirements for electrical apparatus with type of protection 'n'.

This code of practice is prepared from Doc : 85/21906 DC Code of practice for electrical apparatus for explosive atmospheres (of Technical Committee GEL/114 Electrical Apparatus for Explosive Atmosphers) issued for comments by British Standards Institution, U.K.

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